# Soil Erosion and Sedimentation in

# Upper Mill Creek, Fort Jackson, South Carolina

by

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## ABSTRACT

Soil erosion, buffer zone deposition, and sediment transport processes were studied over a five-month period in the upper reaches of Mill Creek, on Fort Jackson, South Carolina. The objectives of the study were to approximate the erosional contribution of dirt roads to sediment detachment and transport, to assess the deposition of eroded soil in wetland buffer zones, and to measure suspended sediment leaving the basin. Repeat cross-section surveys and bulk density samples of selected "rill erosion" road hillslopes and roadside gullies were used to measure soil loss during the period. Soil loss from rainsplash was monitored from small field plots (4.0 $ft^2$). Wetland buffer zone deposition was measured by a series of plastic mats as sediment traps across a buffer transect. Particle-size distributions from wetland buffer zone deposits were measured to evaluate the effectiveness of transport and storage along the buffer zone transects. Suspended sediment concentrations were collected from two tributaries above their confluence and from the main channel below the confluence.

Combinations of instrumentation, field observations, and comparisons with regional values reported in the literature and from model output were used to approximate the relative importance of sediment sources and sinks in the upper basin of Mill Creek. Soil-loss rates and sediment deposition results were used to evaluate erosion, transport, and deposition of sediment from the dirt roads and buffer zones.

Unit sediment mass from dirt road small box plots were significantly higher than forested small box plots unit sediment masses. Repeat surveys of a road hillslope measured a continuous degradation of the slope length profile and a net soil loss of 15.68 $kg/m^2$. Repeat surveys of a roadside gully measured aggradation and degradation of

sediment in the gully and a net soil loss of 1.42 $kg/m^2$. Sediment deposition was found to be significantly improved with buffer zone width. During moderate storms, deposition of sediment across a buffer zone transect indicated substantial deposition of sediment within the first ten meters of the buffer zone and minimal deposition at around thirty meters. Deposition at forty meters had a slight increase due to influence from overbank flows from streams.

Suspended sediment concentrations, stream discharge, and sediment flux rates were examined (especially sediment –discharge relationships) to identify watershed responses. Data stratification by sub-basin, by rising versus falling hydrograph limbs, by first flush phenomenon, by season, and by land-use changes indicated that the relationship between suspended sediment and discharge at the main channel gage site (W1) was complex due to varied responses from the two tributaries. A first-flush of sediment was dominant in the smaller northern tributary (W1N) but also present in the larger eastern tributary (W1E). These high concentration pulses resulted in an out-of-phase relationship between peak discharge and peak suspended sediment concentrations causing variance in rating curves and complex hysteresis. Sediment fluxes from five individual storms as well as overall unit sediment flux and unit flow rating curves indicated no significant difference in sediment loadings between the two tributaries. This is attributed to the importance of large sediment pulses from local erosion-prone sites in both tributaries. In short, a relatively small area of this watershed where substantial sediment contributions are generated dominates sediment production and yield. If such sites can be identified and controlled NPS pollution could be greatly reduced.

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# CHAPTER I

# INTRODUCTION

Concerns with non-point source (NPS) pollution have been fueled by recognition of the harmful impacts of soil loss, channel and reservoir in-filling, degradation of drinking water quality, and the introduction of toxins and nutrients to water sources. Realization of these problems has made the identification and alleviation of such sources imperative. Section 319 of the Water Quality Act of 1987 specifies that the States must implement and enforce the new standards. In recent years, these new regulations have increased concern for and research of NPS pollution. A primary type of NPS pollution is sediment. Soil erosion not only removes the soil surface but may also remove much of the clay, humus, and nutrients from the soil (James, 1998). The organic layer and upper portion of the mineral horizons of soil play a key ecological role. These are the layers from which vegetation draws much nutrients and water. High rates of erosion remove these layers faster than weathering and organic decomposition can rebuild them. Continued removal of the soil A horizon reduces the infiltration capacity of the soil and increases the amount of runoff, which further increases erosion potential (Dunne and Leopold, 1978).

A study area was selected that has two contrasting tributaries, one tributary that is near dirt roads and firebreaks and a second tributary is located in the center of a wetland which acts as a buffer zone and presumably enhances sediment deposition and storage.

This experimental design offers an opportunity to study the impact of roads and buffer zone width on soil erosion, sediment transport and deposition. The purpose of the study was to assess the physical properties of the watershed and channel system affecting the sediment budget of the Upper Mill Creek watershed. Limited local-scale erosion data exist for southern Sandhills watersheds especially for reforested rural watersheds such as upper Mill Creek with very sandy soils, ample relief, and abundant dirt roads. This study provides quantitative and qualitative insights into the physical processes taking place and the effectiveness of wetland storage and dirt road erosion in the Mill Creek watershed.

Study results include estimates of sediment production, deposition, and yield from the two sub-basins. Measurements of interrill and rill erosion rates from specific dirt roads and forested control surfaces are used to determine if substantial contributions to the overall production originate from the dirt roads. Sediment deposition and storage measurements allow the identification of the relative importance of various sediment storage sites and overall changes in storage and particle-size distributions in this type environment. Sediment yields are determined at the base of the two tributaries by sediment sampling and stream gage recording. While an ideal study would include a large number of samples of each of these erosion, deposition, and yield processes throughout the watershed, limited time and resources available for this study severely constrained the number of samples that could be collected. Yet, it was thought that a proper characterization of sediment processes in the basin would require sampling of a diverse array of sediment source and storage areas as well as transport out of the watershed. Thus, this study was designed to gather a limited number of soil and sediment

samples from a variety of environments, to characterize the watershed processes rather than studying a single factor in great depth.

### *SEDIMENT PRODUCTION AND YIELD PRINCIPLES*

#### Soil Erosion

Water erosion is the most dominant soil erosion process in the southeastern United States and includes both detachment and transport of sediment (Colby, 1963). Lal, 1988, defines soil erosion as "the detachment or entrainment of soil particles, thus distinguishing it from deposition and sedimentation transport." Sediment transport is the actual movement of sediment for example, in flowing water (Colby, 1963). Sediment yield is the removal of sediment from a basin. Water moving over the soil is a rudimentary cause of soil erosion. To generate fluvial erosion, water must flow over some type of surface that allows soil particles to be detached and begin transport down slope. Important factors in this process include climate (precipitation and vegetation), basin size, topography (elevation and relief), rock type (resistance and permeability of the surface), and human activity (land-use and management pratices). This complex interaction of climate, geology, hydrology, and topography effects the severity of erosion and soil loss from region to region (USDA, 1983).

Soil erosion is a natural process, but if the magnitude of soil erosion is accelerated then harmful effects may occur. The human factor in soil erosion is highly variable depending on the activity and the environment of the area. Activities such as urbanization, construction, and poor agriculture and forestry conservation practices may lead to severe or accelerated erosion (Ritter, Kochel, and Miller, 1995).

Soil erodibility is a measure of the vulnerability of soil to detachment and movement (Lal, 1988). Rock type characteristics effect the erodibility and infiltration capacities that are responsible for sediment production and runoff amounts of a basin. Soil characteristics such as particle-size distribution, percentage organic content, soil structure and soil permeability are important factors in soil erodibility (Weaver and Lineback, 1981).

## **Hillside Erosion Processes**

### *Rainsplash Erosion*

As rainfall strikes the surface, it contains a relatively large amount of kinetic energy. The applied force by raindrops acts upon the soil surface to detach sediment particles and begin the transport downslope. This initial detachment is "*rainsplash erosion*" (Troeh et al., 1991) which depends on numerous soil and basin characteristics. The most notable characteristic is the soil erodibility, which results from many inherent properties and changes as the soil, reacts to climate, biota, and land-use changes. Soil texture influences the detachment and transport of sediment particles. Course sand particles resist transport while silty and clayey soils have strong cohesive properties that help resist detachment. As the finer grain soils detach and deposit, they may form a crust or impermeable layer which may increase surface runoff (Lal, 1988)

### *Sheet Wash Erosion*

As rainfall intensity exceeds infiltration capacity or soil becomes saturated, and water begins to run off, a different type of erosion takes place. Overland flow erodes the soil surface over time by "*sheet wash*" or "*interrill erosion*" (Dunne and Leopold, 1978). "*Rainsplash erosion*" influences the amount of sheet erosion by entraining particles. The

physical properties of particle sizes, cohesiveness, porosity, antecedent moisture, vegetation, slope gradient, and slope length effect sediment production and the ability of runoff to detach and transport sediment (Colby, 1963). If uniform removal of the soil surface by runoff does not occur, small channels driven by shear stresses of channel flows may form in areas of least resistance. This process of "*rill erosion*", causes an increase in the efficiency and intensity of erosion and transport (Dunne and Leopold, 1978). These two different types of erosion play an important role in modeling soil erosion. Each process is dominated by different forces and requires different calculation methods. Each process also leaves different evidence in the field.

The majority of the sediment generated on hillslopes stays within the basin due to deposition and storage (ASCE, 1975; Lal, 1994; Meade, 1982). The topography and vegetation cover of the area greatly influences this process. Concave slopes, crop field boundaries, floodplains, and reservoirs act as collection points for sediments (Lal, 1988). Sediment yields from a watershed often account for only a small portion of sediment loss by erosion. These deposition areas reduce the energy of the channeled flow that is transporting the sediment particles. Decreased gradient, sloe-length, changes in channel geometry, and increased friction due to rougher terrain and vegetation all reduce the flow velocity. This reduction in velocity allows larger particles to sink due to gravity (Bagnold, 1973).

Evidence of the role of basin size in soil loss and sediment transport indicates that the sediment yield from a watershed is greatest in smaller basins. These generalizations suggest that most sediment is produced in the upper reaches and a major portion of it is stored in the floodplain to be removed through geomorphologic and hydrologic processes

(Roehl, 1962). The "*sediment delivery ratio*" of a watershed; that is, the ratio of sediment yield to sediment production, is an assessment tool of land-use practices and often an objective of erosion models (Dunne and Leopold, 1978; Lal, 1994) (Figure 1-1).

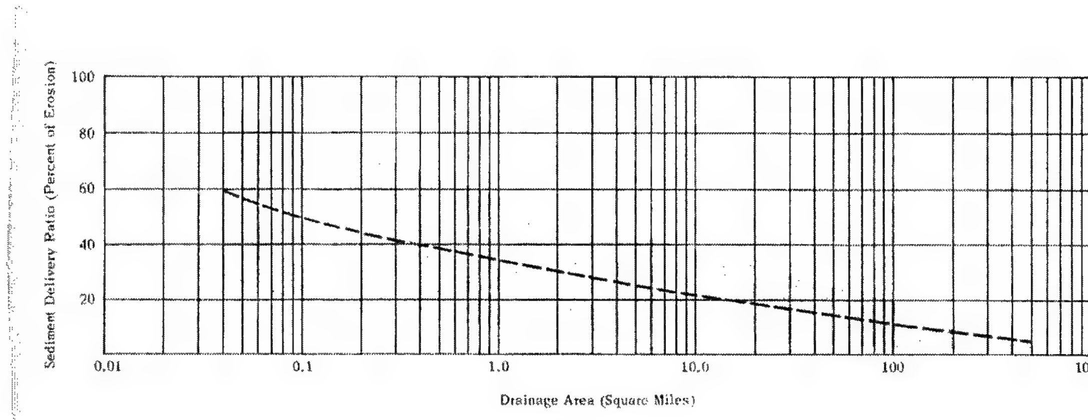


Figure 6–2.—Relationship between drainage area and sediment delivery ratio.

**Figure 1-1. Example, SDR verses Drainage Area**

Source: USDA, SCS National Engineering Handbook, 1975

## Deposition in Buffer Zones

*Buffer zones* are natural filters and traps for both nutrients and sediment that impose important controls for improving water quality, and have been shown to be valuable in reducing the amount of (NPS) pollution to receiving streams. A United States Ddepartment of Agriculture (USDA) recommended average buffer zone width is 50 m (Lowrance et al., 1997). One type of buffer zone is a *riparian buffer*. The USDA defines this as a belt of native trees and shrubs located adjacent to and upslope from bodies of water. Riparian zones consist of three zones. Zone one is typically 5 to 7 meters (15-20 feet) and consists of streamside vegetation. Zone two begins at the end of zone one and extends another 7 to 20 meters (20-60 feet). It is a transitional forest that includes

conifers, shrubs, and some hardwoods. Timbering may be done in zone two if soil stability is not adversely effected and zone one is not compromised. Ruffin (1998) recommends that only 50% of the timber should be removed. Zone three is used if the site is next to tilled or grazed land and it should extend at least 7 meters (20 feet) past zone two. A general rule of thumb is that the width of zones one and two combined should be one-third the distance to the farthest sediment source area (Weik, 1999).

## WEPP Hillslope Erosion Model

Through past examination of standard plots and applying the related plot data to small watersheds and field sites, erosion prediction models such as the Water Erosion Prediction Project (WEPP) is a tool for researching the physical processes involved in sediment erosion, storage, and transport. By utilizing climate, topography, soil characteristics, vegetation, and human activities, careful application of the WEPP model may assist in land-use management.

The WEPP is a physically-based model that predicts erosion, downslope deposition, and sediment yield on a daily time step. It can estimate infiltration, interrill erosion, and rill erosion to predict runoff and sediment yield from an elevated area downslope at a local scale (Morfin et al., 1996). The dominant forces are interrill (raindrop splash and sheet flow) erosion and rill erosion (channelized flow). Effective hydraulic conductivity (Ke) is a major factor in WEPP for calcualting runoff (Elliot, Foltz, and Rembolt, 1994).

WEPP has several conceptual parameters that estimate soil detachment and deposition. The four main input files are management, soil, slope, and climate (Morfin, et al., 1996). The management input file allows for descriptions of vegetation, human

management practices, and initial conditions prior to an event or time simulation. The soil-input file describes soil texture, albedo, percentage saturation, interill erodibility (Ki), rill erodibility (Kr), and critical shear of the soil (tc). It can have up to ten soil map layers (along the hillslope profile) and can extend up to 2 meters in depth. The slope-input file specifies the length and width of hillslopes. A slope length can be modeled in ten different gradients enabling a detailed description of complex topography. The climate-input file describes the daily maximum, minimum, and dew point temperatures, rainfall intensity and duration, and discharge time to peak, solar radiation, and wind speed and direction (Elliot, Foltz, and Rembolt, 1994).

### *STUDY AREA DESCRIPTION*

Upper Mill Creek is located east of Columbia, South Carolina on the Fort Jackson Military Reservation (Figure 1-2). Columbia is located in the Sandhills between the Piedmont and the Upper Coastal Plain. The climate in the Midlands is relatively mild with average annual temperatures of approximately 14 $^{o}$C (low 60s $^{o}$F) and an average annual precipitation ranging from 106 to 120 cm/yr (42-47 inches/yr). From February 1999 to January 2000 the study area suffered from an extreme drought resulting in record low stream flows (SC DNR unpublished data, 2000). For this study, storm events occurring between April through September will be categorized as summer storms and the storm events occurring between October through March will be categorized as winter storms.

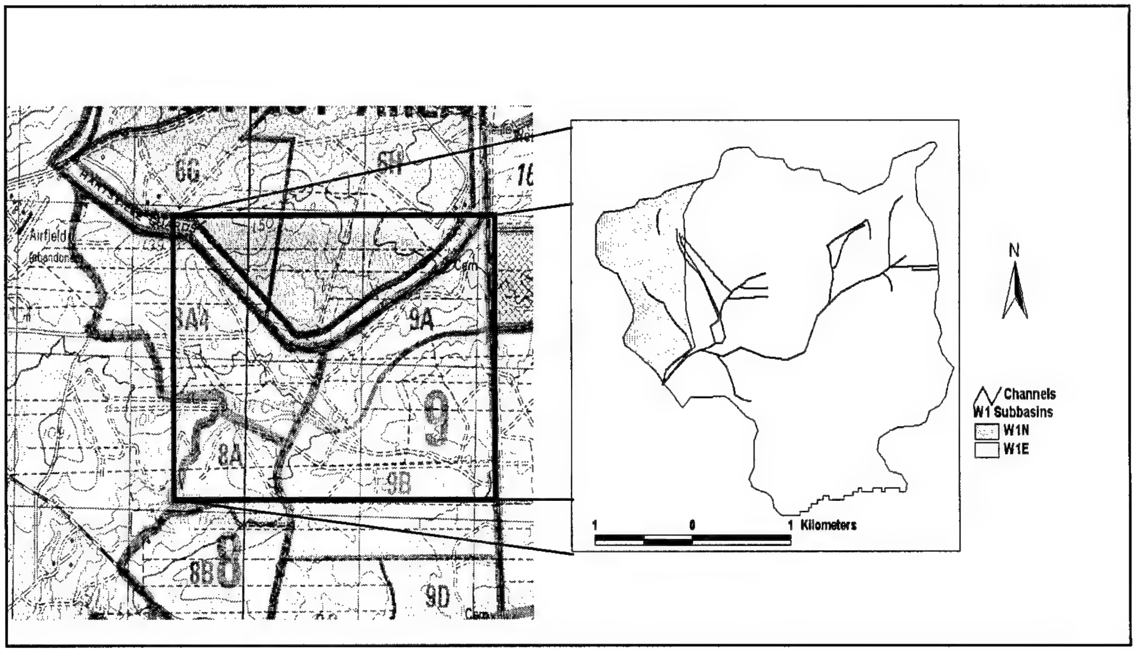



**Figure 1-2. Upper Mill Creek Study Area**

The total area of the watershed is 6.6 $km^2$. The study watershed is in the upper reaches of the west tributary of Mill Creek (henceforth referred to as upper Mill Creek or W1). W1 is mainly forested, with 82.7% woodland area, 1.8% grassland area, 11.7% wetlands, and 3.8% dirt roads (Dean et al., 1998). An extensive system of dirt roads and firebreaks borders and crosses the entire drainage area (Figure 1-3). Based on a preliminary examination of historical aerial photographs, these fire breaks, dirt roads, and range complexes were first introduced between 1955 and 1959. This dense network of dirt roads and firebreaks appears to accelerate soil erosion and act a source of sediment. The channel network largely reflects roadside ditches mapped in the field in 1998 (James, personal communication) and updated by this study. (Figures 1-2 and 1-3).

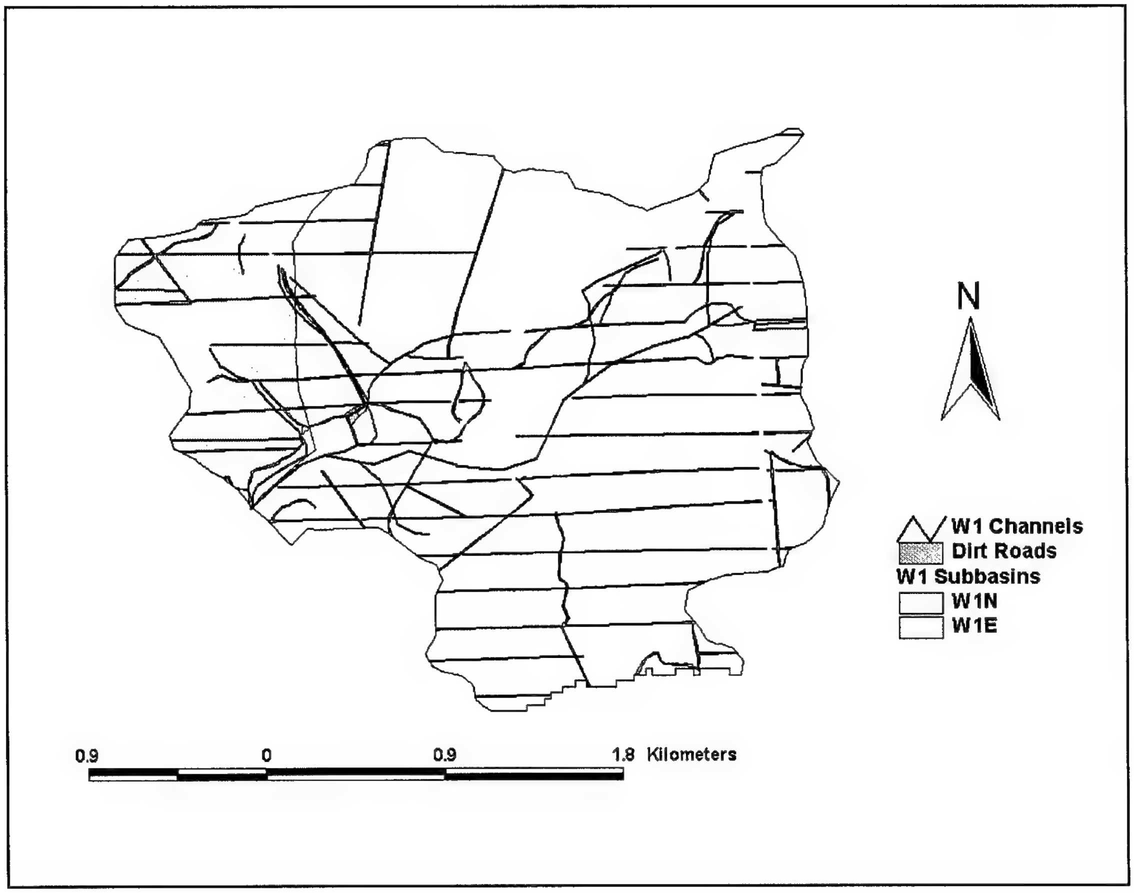



**Figure 1-3. Study Area Dirt Road and Firebreak Network**

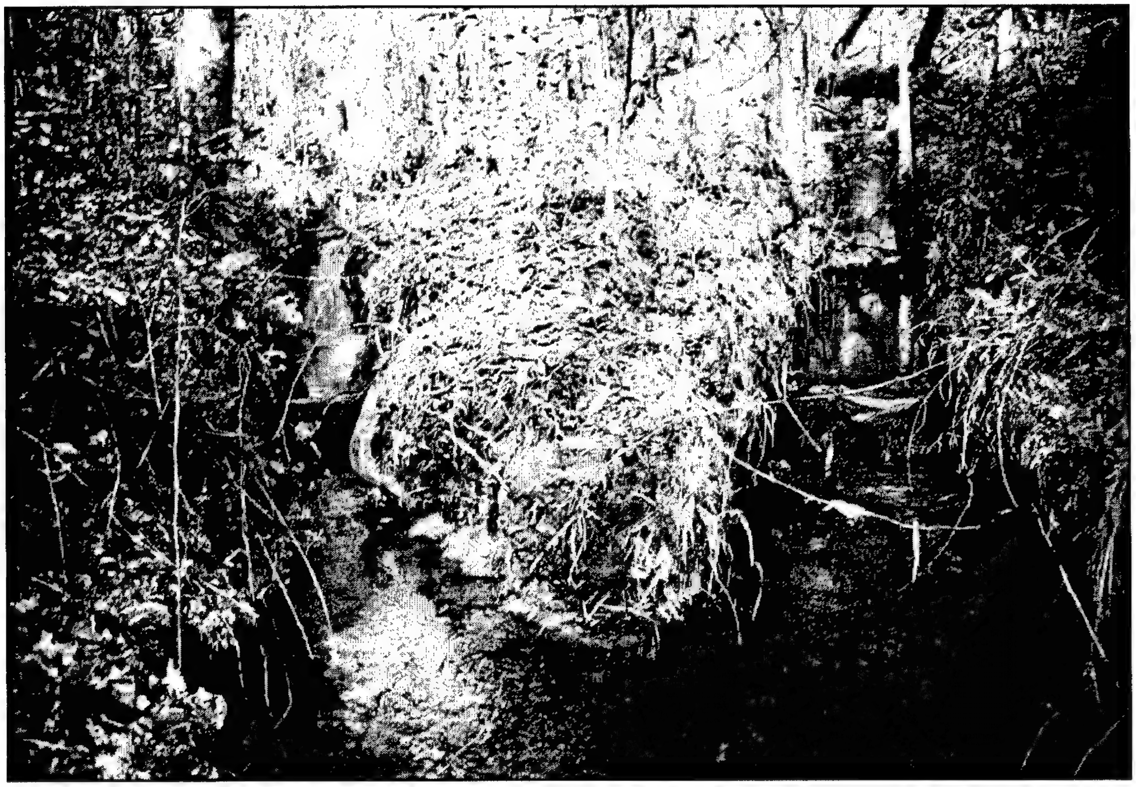


**Figure 1-4. W1N (left) and W1E (right) Confluence at W1 Gage Site (View Upstream)**

The main channel bifurcates a few meters above the W1 outlet into two main tributaries (W1N and W1E) (Figure 1-4). Both channels are ditched and straight in their lower reaches (near the W1 gage). The north tributary (W1N) is paralleled by a dirt road and has direct road runoff entering W1N. W1N has a substantially narrower buffer zone along the channel compared toW1E. The W1E channel ends about 100 m upstream of the outlet within a broad wetland buffer zone approximately three times as wide as W1N. W1E has a large tributary that drains from an active rifle range that supplies a large volume of runoff and sediment. This tributary at one location flows directly on a dirt road for 100 m just prior to joining the W1E channel (Figure 1-5).

**Figure 1-5. W1E Channel Diversion Flowing on a Dirt Road**

**(View Upstream)**

W1N comprises about 20% of the total drainage area of the W1 watershed (Figure 1-6). It has an earthen dry dam about 1000 m upstream from the W1 outlet. The earthen dam has no spillway but a 24 in. culvert allows sediment to be discharged through the reservoir. The W1N ditched channel bottom between the dirt roads and W1 oulet has shown no sign of aggradation or degradation during the study period. W1N crosses a dirt

road and flows through a gently sloping transition into the wetland. From approximately 100 m into the wetland W1N is ditched to its confluence with W1E at the W1oulet.

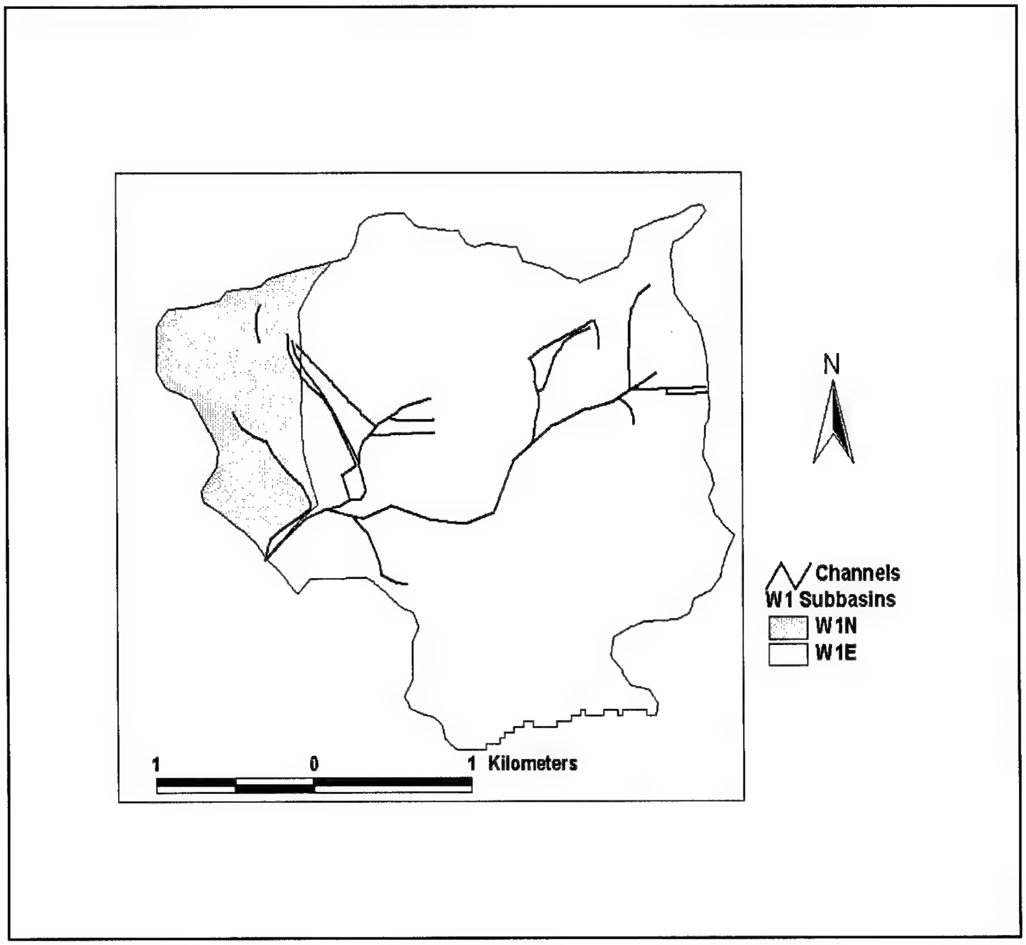



**Figure 1-6. W1N and W1E Drainage Basins within the Upper-most West Tributary of Mill Creek**

W1E comprises about 80% of the total drainage area of the W1 watershed (Figure 1-6). W1E appears to be stable near the confluence, although some upstream reaches in the wetland have aggraded. The head of the W1E channel does not appear to be eroding but unlike W1N, comes to an abrupt end about 30 m below a dirt road named Old Hartsville Guard Road.

Extensive timber harvesting occurred in early December and other assoicated changes in the W1 watershed included road grading, increased vehicular activity, the thinning of pine trees, and the addition of timber debris unto roads and in the W1N and W1E channels.

**Previous Studies**

Studies conducted in 1997 and 1998 (Dean et al., 1998; 2000) provided a base line of stream flow and suspended sediment discharge data for the main W1 channel below the confluence of W1E and W1N. These studies indicated that for high-intensity storms with high antecedent soil moisture, suspended sediment concentrations increased quickly in response to storm events. During an intense convective thunderstorm on 29 July 1997, suspended sediment concentrations peaked early in the event displaying the "first flush phenomenon" (from the W1N channel). A second sediment concentration peak was observed approximately 2.25 hours later and corresponded to the time to peak concentration of the W1E channel. A less intense frontal rainfall event on 26 Oct 1997 produced different results. This storm did not produce the "first flush phenomenon" seen in the high intensity storm but had a slower time of peak concentration with lower sediment fluxes. There was also a second peak sediment concentration observed for this storm (Dean et al., 1998; Atkins, personal communication, 1999). That study suggested that storm type, antecedent conditions, and the physical nature of the basin effects the W1N and W1E suspended sediment concentrations. The fast response with high concentrations from W1N suggests inadequate buffer zones and quick transport of sediment particles along the dirt roads. The slower response from the east channel indicates better buffering, longer travel distances, and slower time to conentrations.

## OBJECTIVES

The W1 watershed provides a good study area to observe the physical processes involved in hillslope soil erosion and sediment transportation in a Sandhills environment. The bifurcation of W1 into two distinct sub-basins enables a study design to compare the effects of soils, vegetation, buffer zone characteristics and land disturbing activities (roads, firebreaks, and timber harvesting) on the erosion and delivery of sediment.

Several hypotheses can be generated and tested concerning these different responses or effects. Hypothesis 1 is that most entrainment and transport of sediment occurs along the dirt roads as compared to forested areas. Hypothesis 2 is that the wetland buffer stores a substantial portion of the total sediment generated resulting in a reduction of sediment transport and delivery to the stream. Hypothesis 3 is that W1N will have a higher sediment yield per unit area than W1E, because (A) it has a much smaller buffer zone along its channel compared to W1E and because (B) the proximity of the road to the channel enhances sediment delivery (Phillips, 1989).

# CHAPTER II

# FIELD, LABORATORY, AND STATISTICAL METHODS

A wide variety of methods were used in this thesis in order to evaluate a range of processes and environments. This chapter which is divided into three sections: field, laboratory, and statistical methods. Field methods include stream discharge measurements, suspended sediment sampling, small box plot interrill erosion measurements, repeat road and gully cross-sectional surveys for rill erosion, bulk density samples, and sediment deposition measurements using artificial grass-mats. Laboratory methods utilized were suspended sediment concentrations through filtration bulk density, removal of organic matter by loss-on-ignition (LOI), sediment textural analysis through wet and sonic sieving. Statistical methods include regression, t-test, and ANCOVA.

## *FIELD METHODS*

Several erosion processes were monitored through field observation and measurements. Discussion of field methods will begin with rainfall, then progress to runoff, erosion, sediment deposition, and sediment yield.

### **Rainfall**

Rainfall data were recorded at the Bravo 9 tipping bucket gauge site, approximately 1.5 kilometers southeast of the study watershed's outlet (G. Carbone, unpublished data). Total rainfall for the study was 61.5 cm with an annual total of 74 cm,

most of which was observed during the period from late June to September 1999.

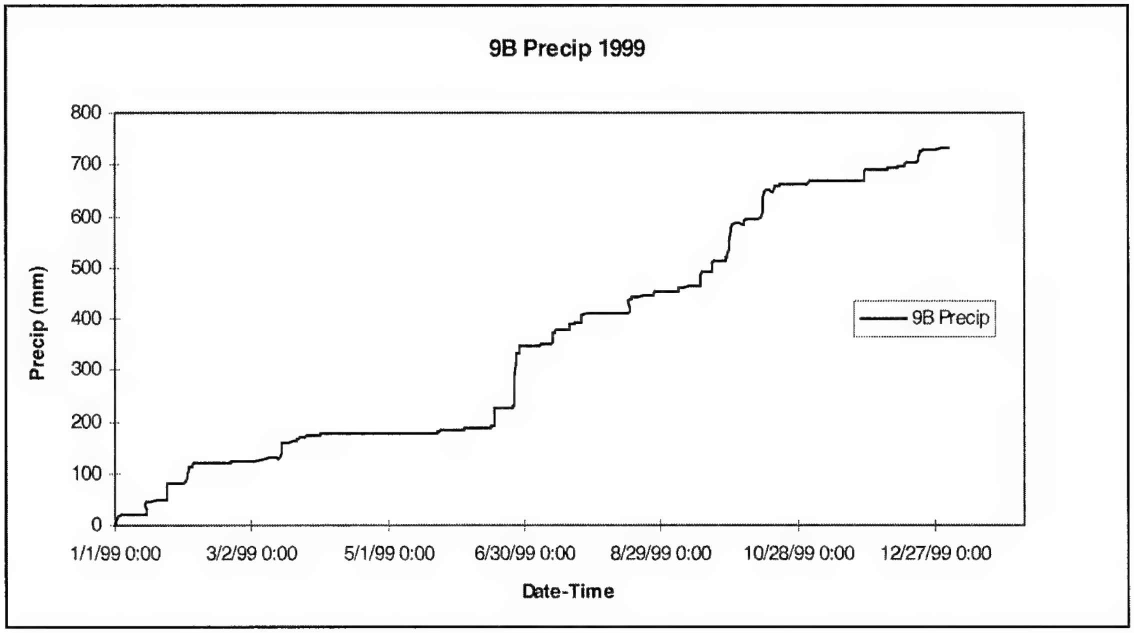



**Figure 2-1. (1999 Daily Precipitation at Bravo 9 Raingage (G. Carbone, Unpublished data)).**

**<u>Runoff</u>**

Previous studies at W1 established discharge functions using data from continuous stage recorders and streamflow discharge measurements of discharge to establish stage-discharge relationships (Dean et al 1998, A. James personal communication, 1998). Sensitivity of the stage recorders was within $\pm$ 1 cm following calibration. The existing W1 stage sensor and data logger has had a continuous record since April 1997. To measure stages at the W1E channel outlet a stage sensor and data loggers were installed on May 19, 1999 to record at fifteen-minute intervals. The initial stage sensor failed and was reestablished June 1999. This instrumentation facilitated the calculation of runoff from stage discharge relationships developed by discharge measurements. Staff gages were attached by rigid wire to metal stakes secured in the

channel bottom. Stage recorders were anchored with rigid wire to plastic pipe stilling wells in the W1E tributary and the W1 main channel and anchored to metal stakes.

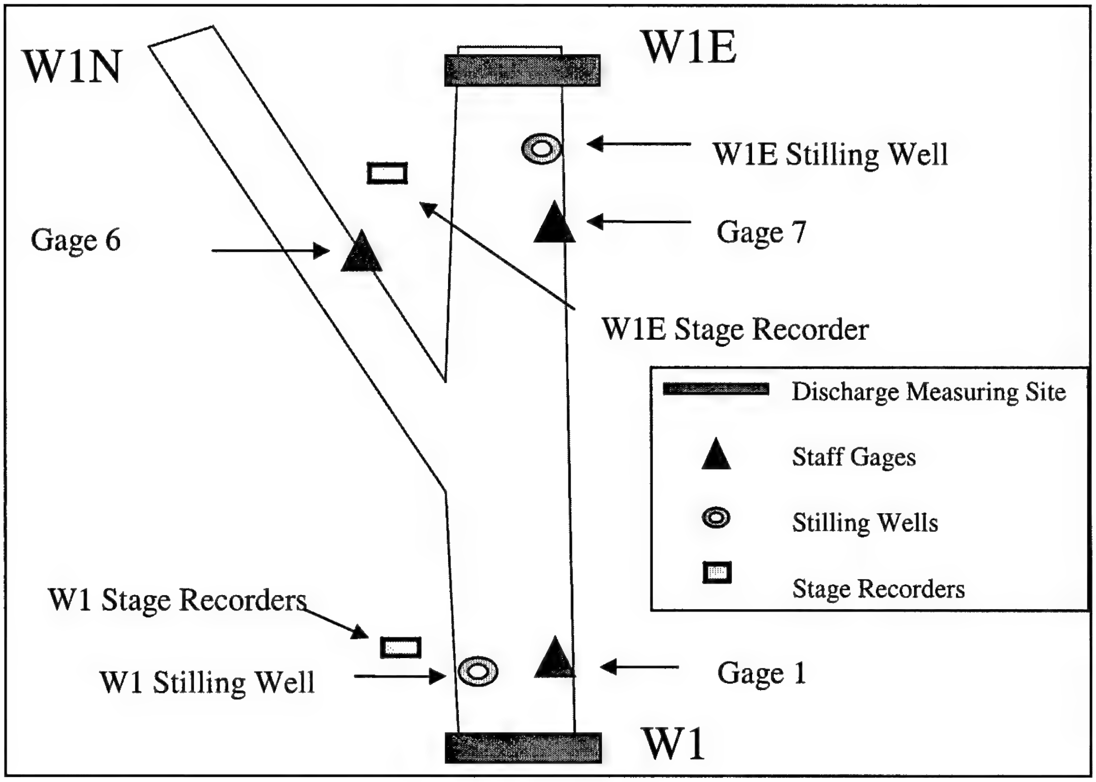



**Table 2-2. Sketch of Gage Site at W1 Outlet and W1N and W1E Confluence.**

Discharge measurements were taken from a cross-section at the W1E sampling site and related to stages at staff gage 7 (G7) at this site. The cross-section was divided into equal 5 cm horizontal segments using a board that was staked across the channel. There were at least 20 sections in all discharge measurements. Given the symmetrical shape and uniform depth of the channel discharge is fairly uniformly distributed across the section. Thus, no single measurement composed a large percentage of the total. A depth reading was taken with a standard wading rod utilizing the .6 method (Dunne and Leopold, 1978). Velocities were measured with a Marsh-McBirney digital flow meter.

The segment areas were calculated with the velocity measurement in the segment center. The segment discharges were calculated and summed to get the channel discharge (e.g. Table 2-1). The stage at G7 was recorded during discharge measurement to establish a stage-discharge rating curve for the W1E tributary (Table 2-2).

In order to convert large amounts of stage data from the data loggers to corresponding discharge the data in Table 2-2 were functionalized by regressing the G7 gage height against discharge using a second-order polynomial (Figure 2-3). This relationship is strong ($R^2 = 0.98$) within the limited range of flows measured. Higher discharges need to be measured to validate the relationship in Figure 2-3. Due to conditions during the study period there were limited opportunities to measure high flows and other field activities often competed for attention during those events. Thus, the discharge for W1 was calculated using the stage-discharge regression from a previous study (Figure 2-4) (Dean et al., 2000).

Given that the W1 stream gage and sediment sampling site is about three meters below the confluence of the two tributaries, it is assumed that changes in storage between the two gages are negligible. Therefore discharge rates of water and sediment passing through the two tributaries should sum to the totals observed as below the confluence. Thus a simple relationship follows in relation to discharge at W1:

$$Q_{W1} = Q_{W1N} + Q_{W1E} \qquad \text{(Equation 1)}$$

Where, Q is discharge (l / s) and subscripts W1, W1N, and W1E refer to gage sites at the W1 outlet, north tributary, and east tributary, respectively. These assumptions allowed calculation of $Q_{W1N}$ by subtracting $Q_{W1E}$ from $Q_{W1}$ instantaneous readings taken within a three-minute sampling period. Changes in flow are typically minimal at this time scale so

$Q_{W1N}$ estimates should be accurate within the precision limits of the individual discharge measurements.

| W1E Q | 26-Jun-99 | | | | |
|---|---|---|---|---|---|
| Interval (Measured Right to Left-Looking upstream) | | | | | |
| **Interval** (m) | Depth (m) | Sect Velocity (m/s) | Sect Width (m) | Sect Area (m2) | Sect Q (m3/s) |
| 0.25 | 0.00 | 0.00 | | | |
| 0.30 | 0.14 | -0.01 | 0.025 | 0.0035 | -0.00002 |
| 0.35 | 0.14 | -0.01 | 0.05 | 0.0070 | -0.00006 |
| 0.40 | 0.20 | 0.00 | 0.05 | 0.0100 | -0.00003 |
| 0.45 | 0.22 | 0.01 | 0.05 | 0.0110 | 0.00007 |
| 0.50 | 0.26 | 0.01 | 0.05 | 0.0130 | 0.00012 |
| 0.55 | 0.27 | 0.01 | 0.05 | 0.0135 | 0.00012 |
| 0.60 | 0.29 | 0.02 | 0.05 | 0.0145 | 0.00027 |
| 0.65 | 0.29 | 0.02 | 0.05 | 0.0145 | 0.00035 |
| 0.70 | 0.29 | 0.05 | 0.05 | 0.0145 | 0.00071 |
| 0.75 | 0.32 | 0.06 | 0.05 | 0.0160 | 0.00102 |
| 0.80 | 0.33 | 0.07 | 0.05 | 0.0165 | 0.00116 |
| 0.85 | 0.33 | 0.06 | 0.05 | 0.0165 | 0.00106 |
| 0.90 | 0.34 | 0.07 | 0.05 | 0.0170 | 0.00119 |
| 0.95 | 0.34 | 0.07 | 0.05 | 0.0170 | 0.00114 |
| 1.00 | 0.33 | 0.06 | 0.05 | 0.0165 | 0.00101 |
| 1.05 | 0.32 | 0.04 | 0.05 | 0.0160 | 0.00068 |
| 1.10 | 0.30 | 0.03 | 0.05 | 0.0150 | 0.00050 |
| 1.15 | 0.29 | 0.02 | 0.05 | 0.0145 | 0.00035 |
| 1.20 | 0.27 | 0.02 | 0.05 | 0.0135 | 0.00033 |
| 1.25 | 0.24 | 0.00 | 0.025 | 0.0060 | 0.00002 |
| 1.30 | 0.24 | 0.00 | | | |
| | | | | **Total Q (m3/s)=** | 0.00998 |
| **Stage Gage 7 (mm):** | **310** | | | **Total Q (L/s)=** | **9.98** |

**Table 2-1. Example W1E Discharge Calculation**

| Date | **G7(MM)** | **Q(l/s)** |
|---|---|---|
| 15-Jun | 270 | 5.83 |
| 16-Jun | 354 | 21.94 |
| 26-Jun | 310 | 9.98 |
| 9-Sep | 260 | 3.63 |
| 10-Sep | 256 | 3.49 |
| 15-Sep | 284 | 8.82 |
| 15-Sep | 310 | 11.32 |
| 15-Sep | 305 | 8.45 |
| 28-Sep | 375 | 25.45 |
| 28-Sep | 355 | 21.05 |

**Table 2-2. Stage Discharge readings at W1E**

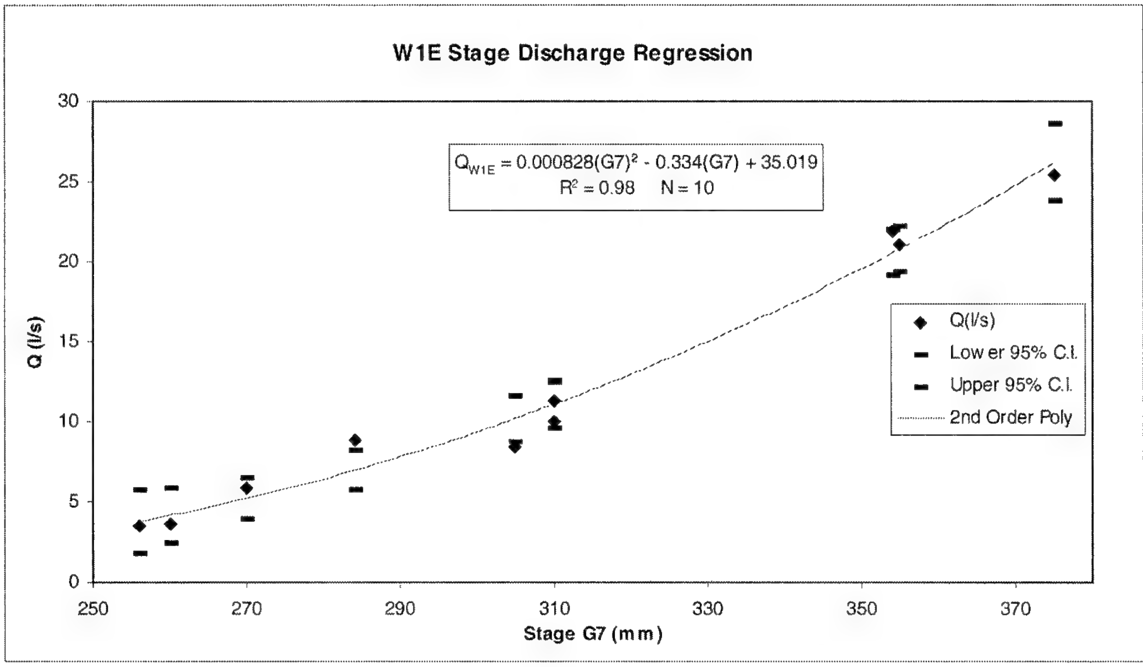



**Figure 2-3. W1E Stage-Discharge Rating Curve (G7 is staff gage height at W1E)**

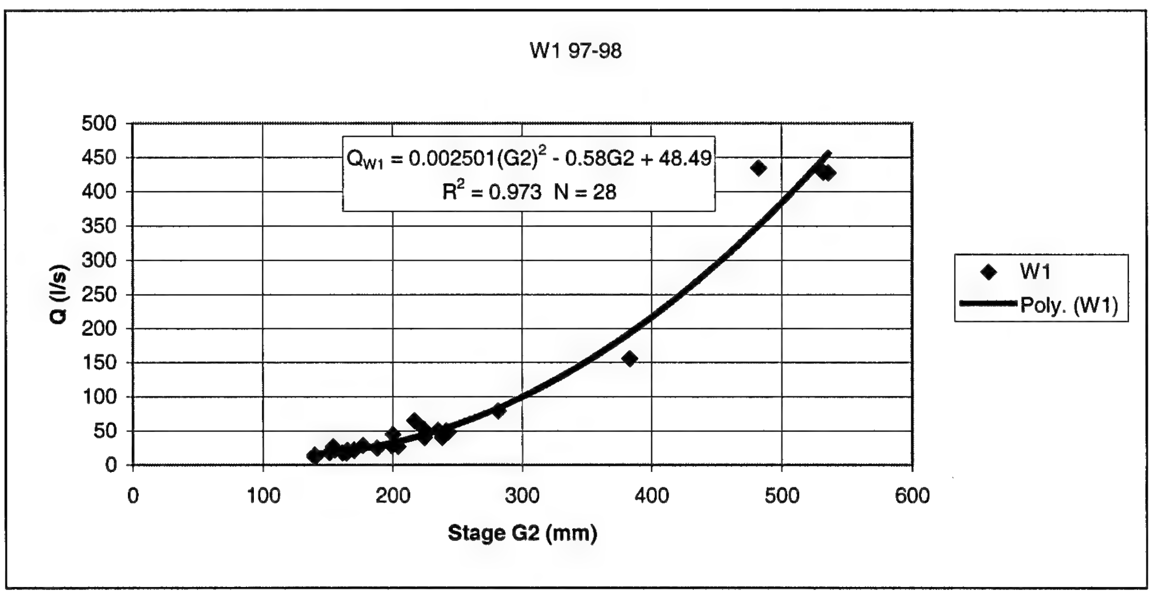



**Figure 2-4. W1 Stage-Discharge Rating Curve (Dean et al., 1998)**

## Sediment Production

Interrill box locations were constructed at four sites: R1, near the outlet on the W1N tributary, R2 upstream of the W1E tributary in proximity to the clay pit, R3 upstream on the W1N tributary near the check-dam, and R4 upstream of the W1E tributary near the W1E large tributary (Figure 2-5). Interrill sediment was measured using a small-field box plots described in Lal (1994). Each interrill field plot consisted of a 4.0 $ft^2$ wooden box which was placed on sites representative of the dirt roads or in the forest as controls. The box has a spout on its lower end that emptied runoff and sediment into a 500 ml collector (Figure 2-6).

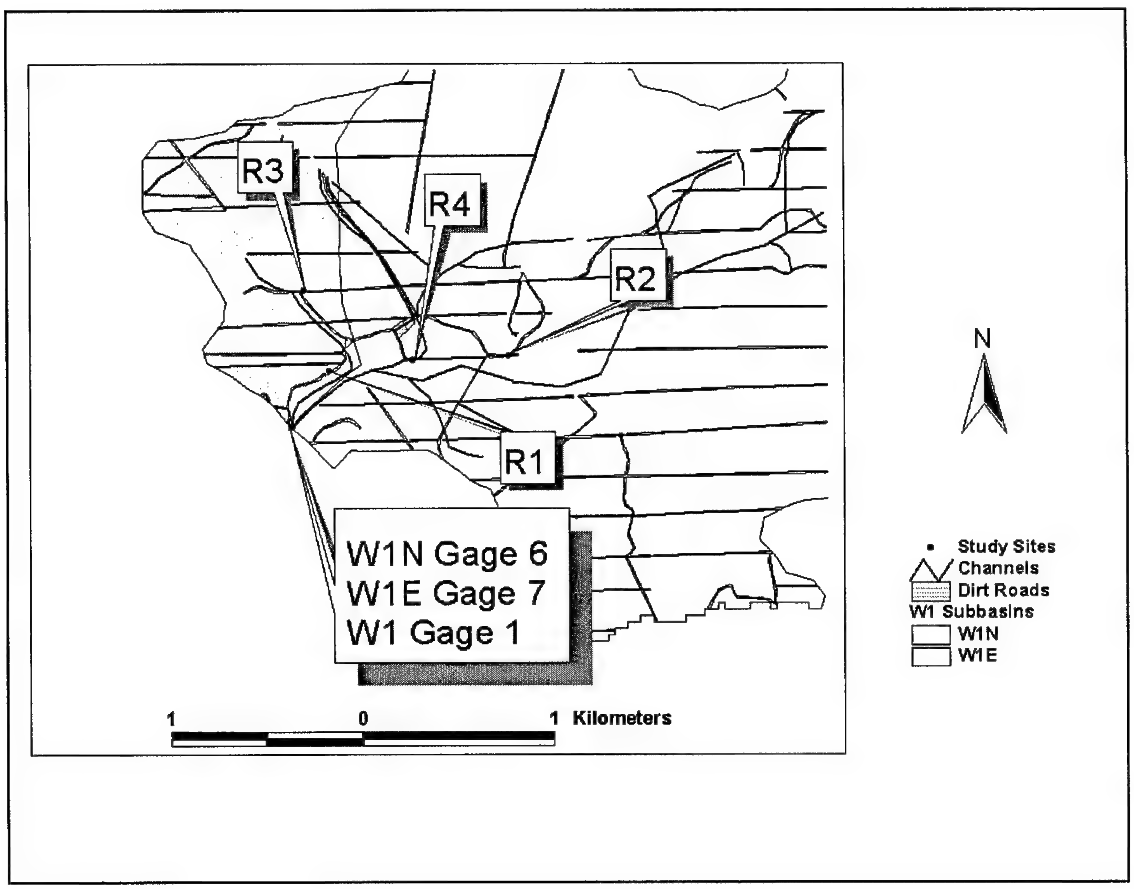



**Figure 2-5.** Interrill and Rill Erosion Sites

**Figure 2-6.** Small Box Plot (Interrill Box)

Rill erosion sites were at the R3 and R2 sites, the hillslope profile was at R3, and the gully cross-section was at R2 (Figure 2-5). Erosion and deposition along dirt road rills was measured with cross-section profiles across rills at monumented locations (e.g. Sirvent et al., 1995). On the dirt road hillslope (R3 site) (Figure 2-7) four cross-sections were measured (0 m, 15 m, 45 m, and 75 m) along with a slope profile down the middle of the road at 0 m, 15 m, 35 m, 60 m, 75 m, and 98 m. The cross-sections were surveyed with a manual transect using, 100 m surveying tapes, and a 7 m survey pole to take readings at about 5-cm intervals. The R2 site was a roadside gully approximately 1 m wide with a slope of 2 percent (Figure 2-8). Two cross-sections approximately 2.3 m

across and 2.6 m apart were measured at 1-cm intervals by placing a level line across the tops of monumented survey stakes and measuring the cross-section depth with a metric ruler. Cross-section areas were calculated using the same procedure as in the discharge procedure. Erosion volumes were calculated as the product of the difference in areas and the hillslope distance between cross-sections.

Bulk density samples were collected using a 100-cm3 cylinder. Bulk density was used to convert sediment volumes to mass to assess the amount of sediment being entrained and deposited. Samples were taken along the soil surface in areas with no pebbles or macro organics at approximately 5 cm depths. Two samples were taken in the side spoil generated from recent grading and three samples were taken from within rills representative of surface along the hillslope.

**Figure 2-7. R3 Hillslope Survey Location, View to east, rill on right side developed since grading in March 1999. (Photo in December 1999)**

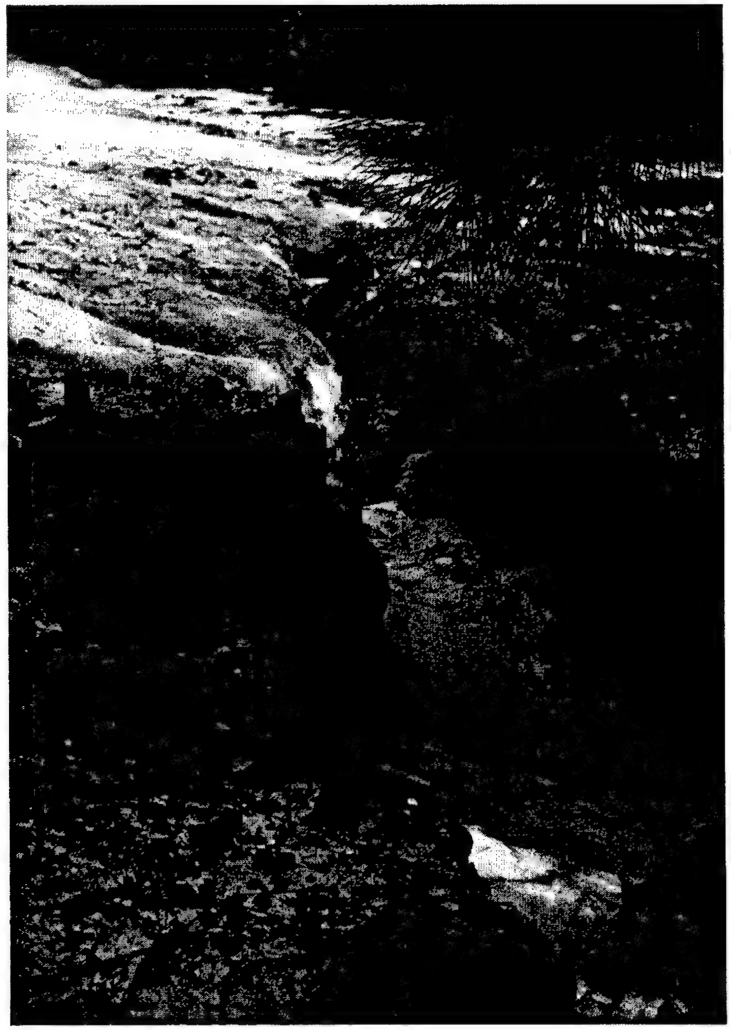


**Figure 2-8. R2 Gully Survey Location. Dirt Road north of Old Hartsville Guard Road that empties into W1E (December 1999)**

## Deposition

Wetland buffer-zone deposition was measured utilizing plastic mats (Figure 2-9) systematically placed in representative areas of likely deposition below roads at wetland boundaries. Depositional mats were placed in the same general location as the four erosion sites. M1 was along W1N above the ditched channel at the edge of the wetland, M2 was above W1E below the sand pit, M3 was on W1N below the earthen check dam, and M4 was above the W1E ditched channel (Figure 2-10). Mats were placed at intervals

between 10 m – 15 m inside the buffer zone starting from the road and toward the channel and secured with six-inch turf spikes. Depositional mat transects topography had only slight relief with slopes less than two percent. Vegetation varied little between sites and consisted of mainly pines, hardwoods, evergreen shrubs, and grasses. Each mat had an area of 0.297 $m^2$ and was a rigid plastic turf that had a roughness value higher than the surrounding surfaces due to the vertical rigidity and density of the 1- cm artificial grass blades. Additionally, the secured mat was not washed aside like the pinestraw, leaves, and grasses that dominated the litter layer. Thus sediment deposits may have been greater than on adjoining areas. Nevertheless, spatial patterns of deposits should be representative of natural surfaces. Field observations after storm events found little visual difference between texture of sediment deposits around the mats trapped by underlying grasses, roots, and sticks and sediment deposited on the mat.

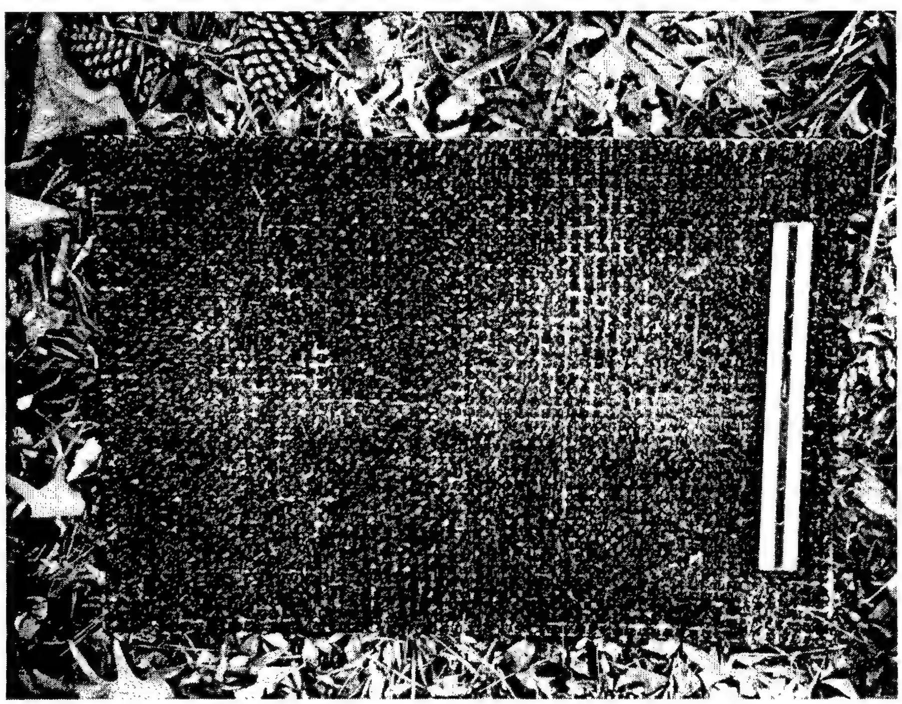


**Figure 2-10. Depositional Mat Photo. Ruler is one Foot in Length**

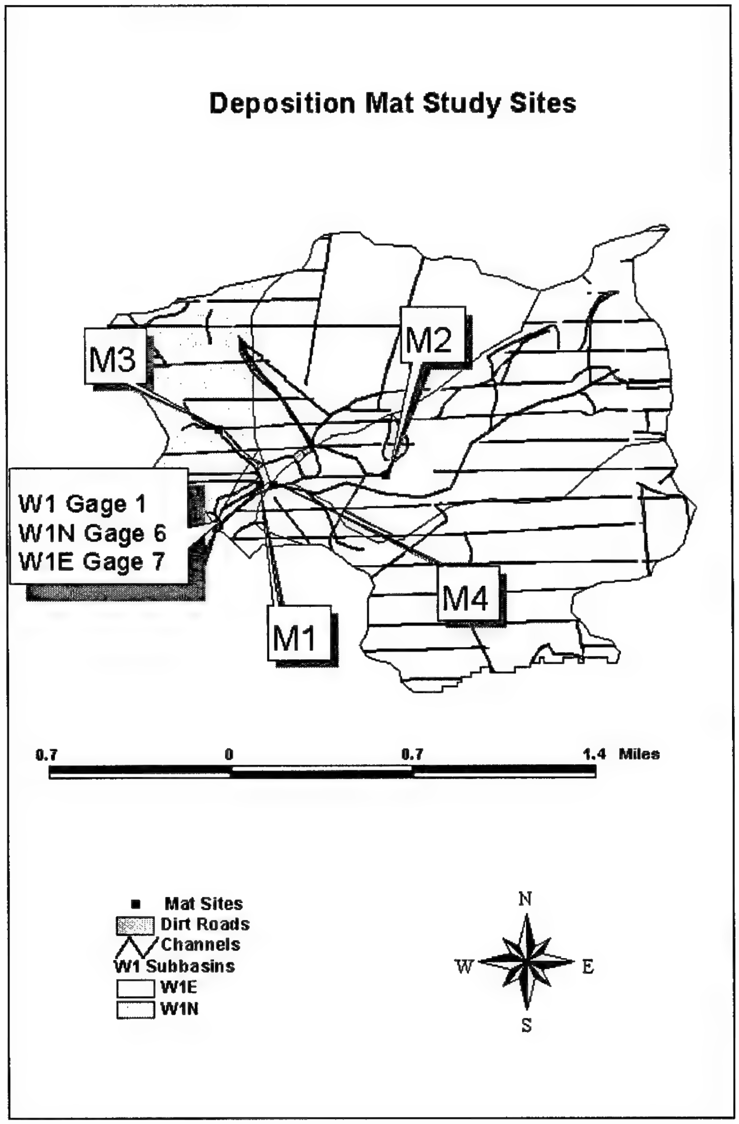



**Figure 2-10. Depositional Mat Locations**

## Sediment yields

Manual depth integrated (grab) methods (Hadley and Walling, 1984) were used to collect 500 ml suspended sediment samples, at W1N, W1E, and W1. In addition, an automated ISCO sampler (ISCO, 1996) was used to sampled at W1 with the intake positioned in the center of the channel for the intermittent periods through August 1999. These techniques allow for representative samples of suspended sediment particles (Horowitz, 1991). Manual sampling followed guidelines in the USDA, SCS, National Engineering Handbook, Chapter 4, 1975.

Given the short distances between gages (Figure 1-4) and the small amount of bed material in the channels, changes in sediment storage between the W1, W1E, and W1N sediment sampling sites were assumed negligible. Therefore, sediment yields at the mouth of the two tributaries were assumed to sum to the total yield below the confluence:

$$Qs_{W1} = Qs_{W1N} + Qs_{W1E} \qquad \text{(Equation 2)}$$

Where Qs is sediment discharge (g / s). This is similar to the assumption made for runoff (Equation 1) except that sediment tends to travel in pulses so the three-minute time difference between the samples could be more critical. To test validity of the relationship assumed by equation 2 sediment samples were collected at all three gages and discharges calculated at all three sites.

### *LABORATORY METHODS*

## Bulk Density

Bulk density is the ratio of dried mass to volume (g/cm$^3$). Bulk density was determined for erosion cross-section samples by drying the 100 cc samples overnight at 103 $^0$C, cooling in a dessicator, and weighing (Blake and Hartge, 1986). Collected

samples had little to no macro organics, which were, therefore, included in the overall weight.

**Deposition Mat Sediment**

Mats were carefully lifted in the field and transported to the lab in plastic bags. Larger particles were removed to a 500-ml beaker and bags and mats were thoroughly rinsed into a 5-gallon bucket. The sample was allowed to settle for 72 hours, the excess water was drained, the sediment moved to a labeled beaker, dried at 103 $^0$C for 24 hours, and weighed using an analytical balance. A unit sediment mass was obtained by dividing the total dried weight by the mat area. The sediment was then stored in a dessicator prior to particle size analysis.

**Organic Matter**

To determine the mass of organic matter in the mat-deposition samples, the loss-on-ignition (LOI) method was used as described in the Standard Methods for the Examination of Water and Wastewater (Eaton et al., 1995). Samples were placed in a muffle furnace and heated at 550 $^0$C for forty minutes. The sample was removed, allowed to cool in a dessicator, and weighed. The percentage organic matter lost was calculated as:

$$\%OM = \frac{W_d - W_I}{W_d} * 100 \qquad \text{(Equation 3)}$$

where % OM is percent organic matter, $W_d$ is mass of dried sample, and $W_I$ is mass of the ignited sample.

**Particle-Size Distribution on Deposition Mats**

*Wet-sieving*

Once the sediments from the deposition mats had been dried and the organic matter removed by LOI, the samples were wet-sieved and sonic sifted to determine the fine and sand fractions. The sample was carefully ground in a mortar to break up aggregates using a rubber-tipped pestle. From the sample, 30 grams (or the entire sample if less than 30 grams) was remove with a plastic spoon and placed in a 63um sieve, and fines were washed out by a steady stream of water. The remaining material was extracted, placed in a beaker, oven dried at $103^0$C for 24 hours, cooled, and weighed to get the total mass of sand. The difference from the original mass was the percent fines:

$$\%F = \frac{W_d - Ws}{W_d} * 100 \qquad \text{(Equation 4)}$$

where % F is percent fines and Ws is weight of sieved sediment. The remaining material was then sonic sifted to get the sand distribution.

*Sonic Sifting*

An ATM sonic-sifter was used to analysis sand particle-size distributions (ATM, no date). The sieves were cleaned by gently tapping each individual sieve. Six plastic sieves with a wire mess of decreasing geometric size from 2000 um to 63 um were used. The sieves were stacked in the following order: 2000, 1000, 500, 250, 125, and 63 um. Approximately 15 -20 grams of dry wet sieved material was placed in the top sieve and inserted into the sifter. The material was sifted for 7.5 minutes in the sift/pulse mode on a

setting of 8. Each sieve was removed, weighed, tared, cleaned, and weighed again to get the mass of material of that fraction. These masses were then recorded and converted to percent of total sand distribution:

$$\% S_i = \frac{W_i}{W_s} * 100 \qquad \text{(Equation 5)}$$

Where $\% S_i$ is percent of sand fraction of a given sand grade (after removal of organics and fines) and $W_i$ is the weight of sand on a given sieve.

**Suspended Sediment Concentration**

Suspended sediment concentrations were measured, using the same lab procedures as previous studies to allow comparisons and extension of the sediment concentration data set to the historical record for 1997-1998 at W1 (Dean et al, 1998). Samples were refrigerated at 4 $^0$C until suspended sediment concentrations were measured. Laboratory procedures are outlined in Standard Methods for the Examination of Water and Wastewater (Eaton et al., 1995). This procedure begins by weighing a clean oven dried (at 103 $^0$C) 0.70 um fiberglass filter which is placed on a vacuum filtration device. A known volume of approximately 75-ml of well-stirred sample was extracted while the sediment was in motion and uniformly distributed. The subsample was filtered. Using a vacuum filtration device that was thoroughly rinsed with distilled water. Filtration was continued for an additional three minutes following rinsing to remove excess water. The filter with residue was removed and placed in a numbered aluminum dish, dried at 103 $^0$C for at least three hours, removed to a dessicator, allowed to cool, and then weighed on an analytical balance. The dry filter weight was subtracted from the total dried residue and filter weight to obtain the suspended sediment weight, which was

divided by the extracted sample volume to get a suspended sediment concentration in mg/l. Quality assurances and checks (QA / QC) were made with every 10 to 12 samples to ensure lab procedures are producing accurate measurements (Eaton, et al., 1995, Dean et al., 1998).

Sediment flux was the product of the suspended sediment concentration (mg/l) and the discharge (l/s) at the time the sample was taken. This product is a sediment flux of mass per unit time (mg/s). This sediment flux was convert into units of kg/d. To compare flux rates between the W1E and W1N watersheds the flux was divided by drainage area to yield unit sediment flux (kg/d/km$^2$)

### *STATISTICAL METHODS*

Field samples represent a relatively small sample of conditions observed that vary greatly in time and space, so statistical relations are emphasized over individual observations. Extrapolation of data outside the observed ranges may result in erroneous conclusions. Soil erosion models were employed to assist with the interpretation of observations. Given difficulties with model calibration and validation, limited time, and resources available to this study, modeling was only exploratory and results should be considered preliminary. Field measurements of erosion, sediment concentration, and storage were piecemeal so some was qualitative by necessity. Statistical test were done using data analysis tools for Microsoft Excel for Windows 95 (Microsoft, 1995) and SAS procedures (SAS Institute, 1998).

#### **Regression Analysis**

Regression analysis was used to functionalized stage discharge relationships, deposition along buffer zones, and analysis of suspended sediment concentration and

discharge in determining sediment rating curves (Meade, Yuzyk, and Day, 1990; James 1998). Data were stratified by season, type of precipitation event, rising versus falling limb of hydrographs, year, and land-use change to assess conditions and determine sediment load variability as a function of discharges (Meade, 1982).

**Coefficient of Variation ($R^2$)**

The coefficient of variation was used to measure the percent variability of the observed dependent variables as explained by the variability of observed independent variables. This measure was used in regressions of flow stage on discharge, depositional mat unit weight distributions on distance, and sediment concentrations (rating curves) on discharge. A high value of $R^2$ indicates a strong association between independent and dependent variables and represents the percent variance in the dependent variable as explained by the independent variables (Moore, 1993).

**T-test**

The t-test method is used to determine if the difference between two means is significant. This test was used on Hypothesis one, two, three, and on quality assurances and checks on laboratory procedures. For each Hypothesis the null hypothesis ($H_o$) was evaluated; that is that there was no difference between means. $H_o$ was rejected if the t-test indicated significant difference at the alpha = 0.05 level. Null Hypothesis 1 was tested by the difference between observed soil loss from dirt roads against forested control sites. Null Hypothesis 2 was tested by the difference between sediment deposition and particle size distributions at various positions in the buffer zones. Null Hypothesis 3 was tested by the difference between storm unit sediment flux (kg/d/$km^2$) at W1E and W1N for five

storm events. Quality assurances and checks were paired repetitive samples, which were tested for significant difference from zero.

## ANCOVA

Analysis of covariance (ANCOVA) evaluates quantitative variables by classification with a qualitative variable by calculating an F-statistic which, when compared to an F-value based on the alpha level and degrees of freedom, test the significance of differences in regression slopes under the stratification of the descriptive qualitative variables. Using analysis of covariance (ANCOVA) inferences on the differences between previous study data and this study data to determine compatibility. ANCOVA was used to evaluated W1N and W1E unit flux unit flow rating curves and a pre-timber harvesting curve against a post-timber harvesting event to reflect any significant difference.

# CHAPTER III

## DATA ANALYSIS AND RESULTS

### *SAMPLED EVENTS*

Nine storm events were sampled during from February 1999 to January 2000. This represented most of the larger storms during the study period plus a few small events (Figure 3-1). Anticipated limitations of this study included the need to reach the study area quickly before the onset of storms to capture the initial rising limb response. Travel time, precipitation spatial variability, and distances between sample sites constrained the collection of data. During storms, priority was given to suspended sediment sampling but field observations across the basin were also necessary to evaluate the spatial nature of responses from sediment sources, runoff, buffer zone effectiveness, and wetland inundation. Total rainfall for the study period (February 1999 to December 1999) was 61.5cm compared with a total of 74 cm which was about 40 cm below the annual mean (unpublished data, Carbone, 2000; US Dept. of Commerce, 1992).

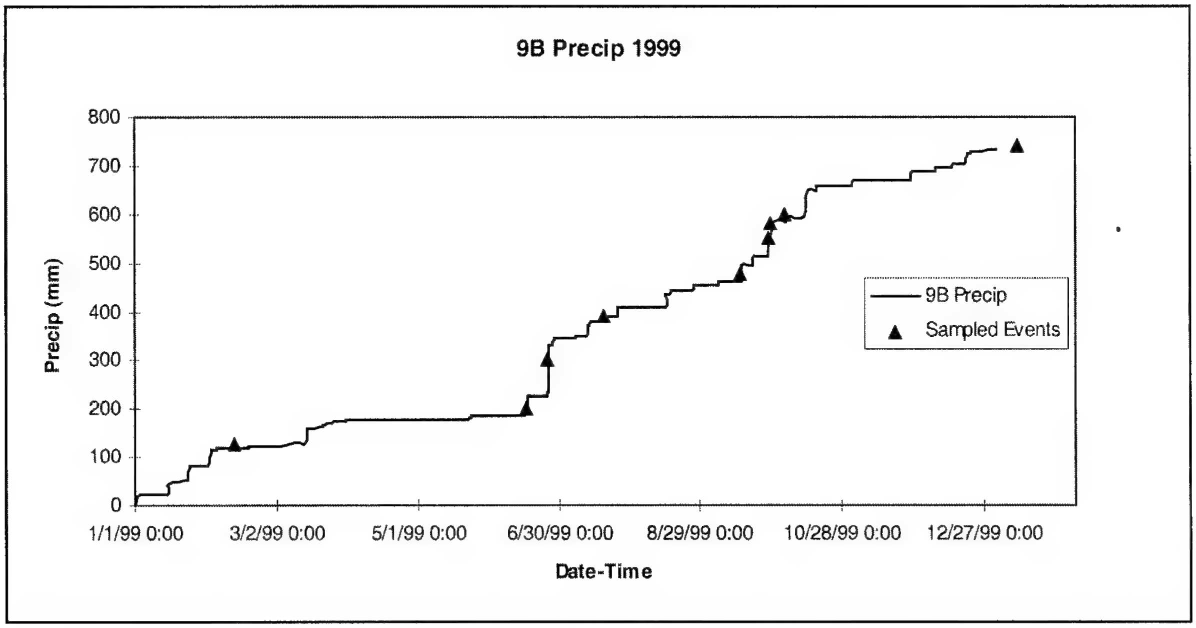



**Figure 3-1. Sampled Events and the precipitation record at Bravo 9 Rain Gage (Rain Data Unpublished, Carbone, 2000)**

*SEDIMENT EROSION*

**Rill Erosion**

Rill erosion susceptibility along the dirt roads was evaluated by monitoring cross-section surveys along the hillslope at R3 and a gully at site R2 to estimate profile changes through time and cross-sections and volumes were calculated from net changes between surveys. The R3 hillslope had a profile length of 98 m, width of 4 m, and an average slope of 5%. The R2 gully survey site was 2.6 m long, 2.3 m wide, with a slope of 1%.

*R3 Hillslope Profile*

The R3 profile was measured in two ways. Four separate cross-sections and the right center (1.5 meters from the right side, viewing uphill) profile were monitored from June 1999 to November 1999. This represented the areas of maximum erosion activity. During the six month period (mid June 1999 to early November 1999) the cross-section

soil loss was 15.68 $kg/m^2$. This represents erosion of approximately 140 tons/ac/yr (Table 3-1) based on a road surface area calculated as the segment length (m) times the roadway mean width (4 m). If this rate continued for another seven months the soil loss would exceed the tolerance (T) factor in the county soil survey of 3 tons/ac/yr (Lawerance, 1978). The greatest soil loss was measured near the base of the hillslope. This indicates that sediment is being effectively transported downslope and off the slope. Local deposition began to occur beyond the 98 m point of the hillslope base and extended about five meters until it reached the forest edge. At this location the road gradient is minimal at one to two percent. The gradient slopes away from the hillslope toward the W1N tributary. Field observations monitored the continued existence of a sediment plume that is formed at the edge of the forest and extended eight meters below the road (Figure 3-6). Prior to the study, most dirt roads were graded leaving the roadway at R3 smooth with loose sediment material. Subsequent surveys characterize the development of rills mainly on the lower south side of the road looking uphill (Figures 3-2 to 3-5; cf. Figure 2-7). Each cross-section had periods of deposition and erosion reflecting the downward movement of sediment. The dominant areas of erosion and rill development were on the lowest side of the road where flow velocities are maximized. Another area of high rill development was the embankment of spoils from grading on both sides of the roadway. Deposition occurred mainly on the north side at the base of the embankments where the roadway had the smallest gradient.

| R3 Cross-sections | 0m - 15m | 15m - 40m | 40m -75m |
|---|---|---|---|
| Average Area of Net Erosion(m^2) | 0.0352 | 0.0501 | 0.0655 |
| Segment Length (m) | 15 | 25 | 35 |
| Volume (L) | 528.0 | 1252.8 | 2290.8 |
| Bulk Density (g/cc) | 1.52 | 1.55 | 1.59 |
| Net erosion (kg) | 803 | 1942 | 3642 |
| Unit Net Erosion (kg/m^2) | 10.70 | 15.53 | 20.81 |
| | Average Unit Erosion (kg/m2) | | 15.68 |

**Table 3-1. R3 Cross-section Soil Losses (Distance Measured from top of Hillslope)**

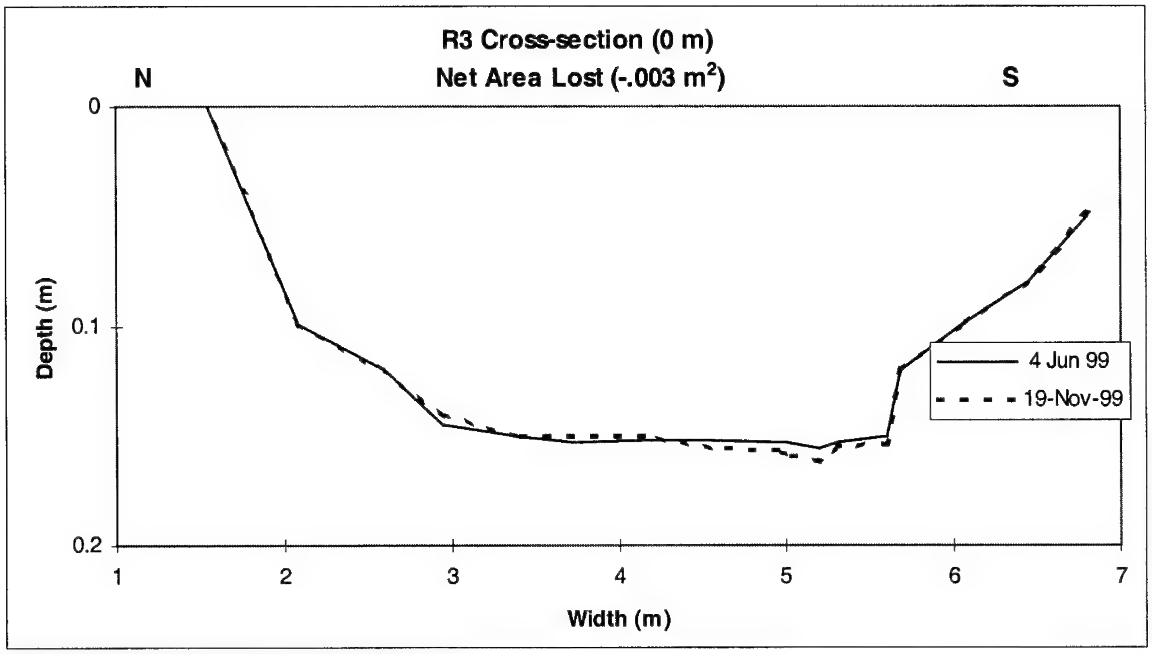



**Figure 3-2. R3 Cross-section Soil Losses at 0 m (See page 22)**

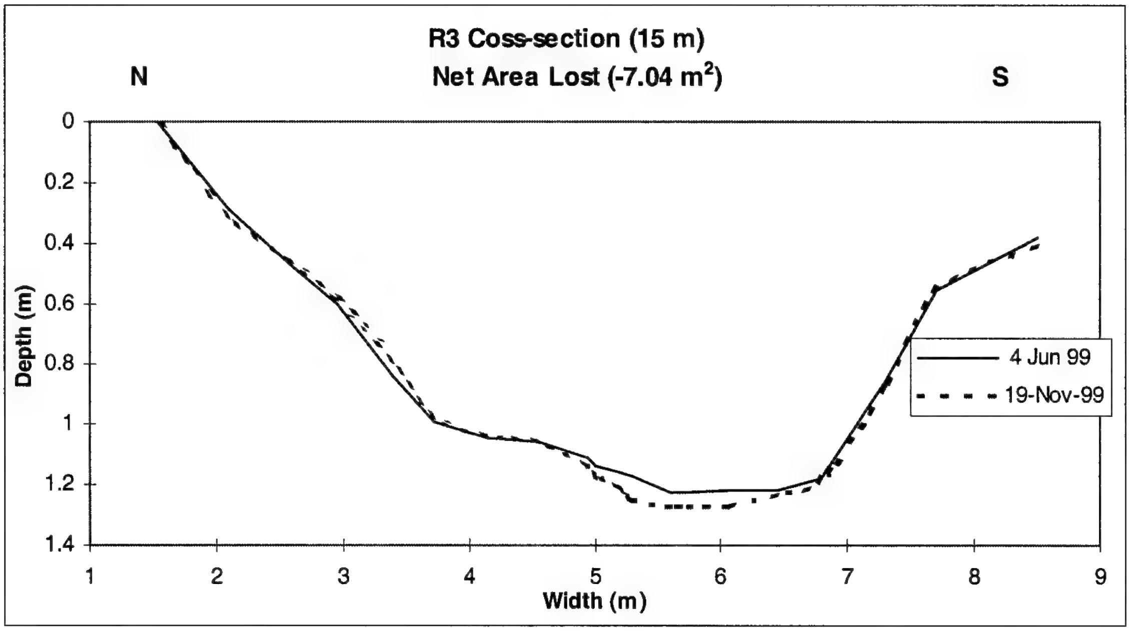



**Figure 3-3. R3 Cross-section Soil Losses at 15 m**

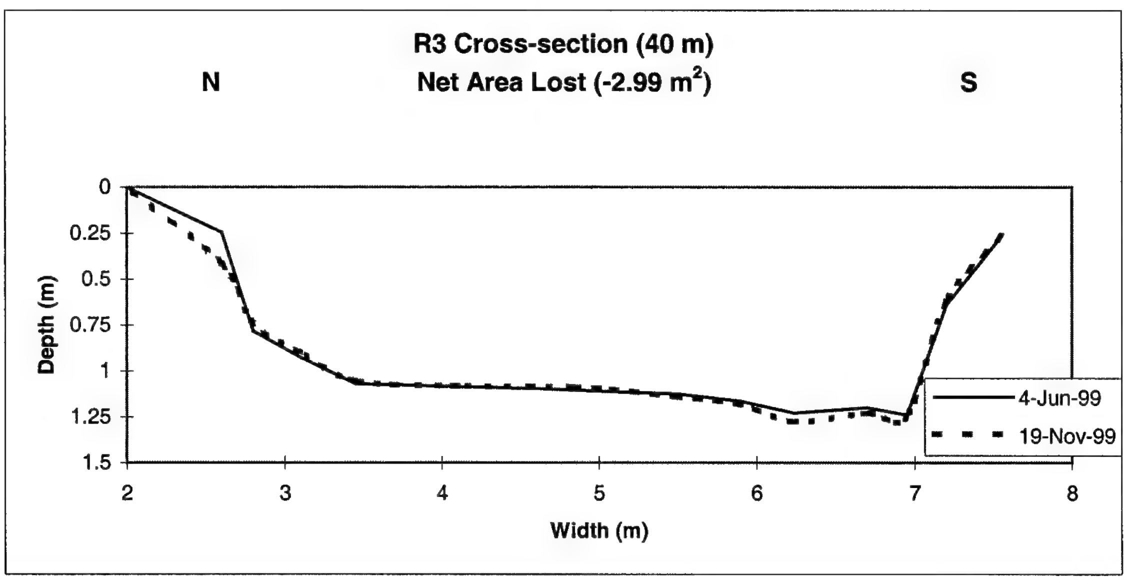



**Figure 3-4. R3 Cross-section Soil Losses at 40 m**

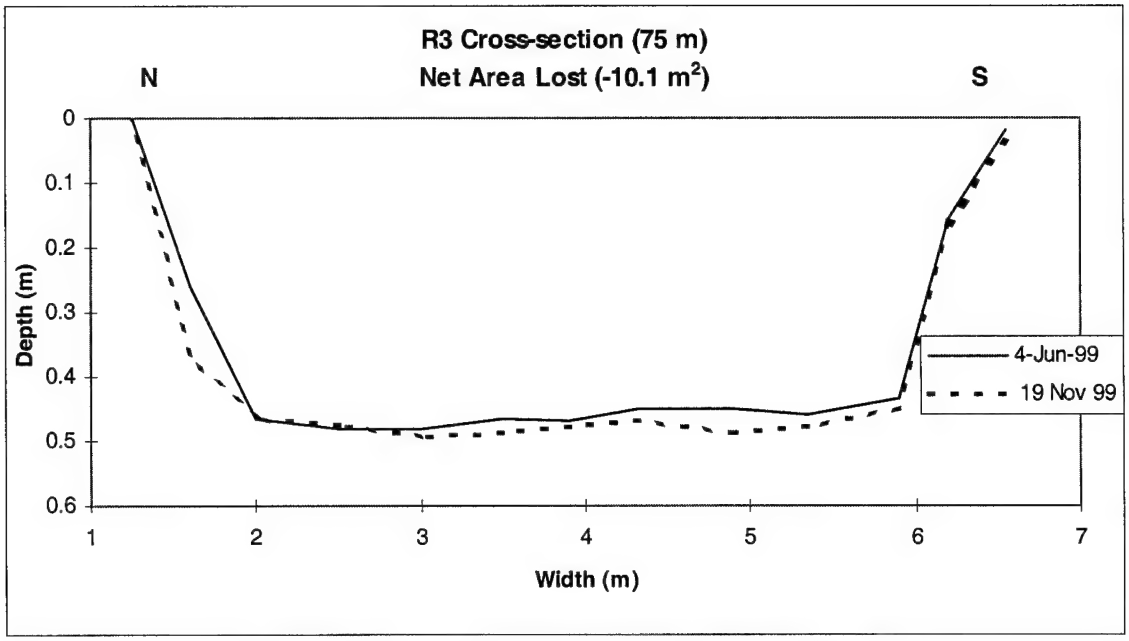



Figure 3-5. R3 Cross-section Soil Losses at 75 m

Figure 3-6. Sediment Deposition below R3 Hillslope Base, Looking Downhill

Toward W1N Channel Below Earthen Dam

The right centerline profile indicated a continual loss of sediment down-slope (Figure 3-8). This profile also indicates efficient sediment transport with no deposition.

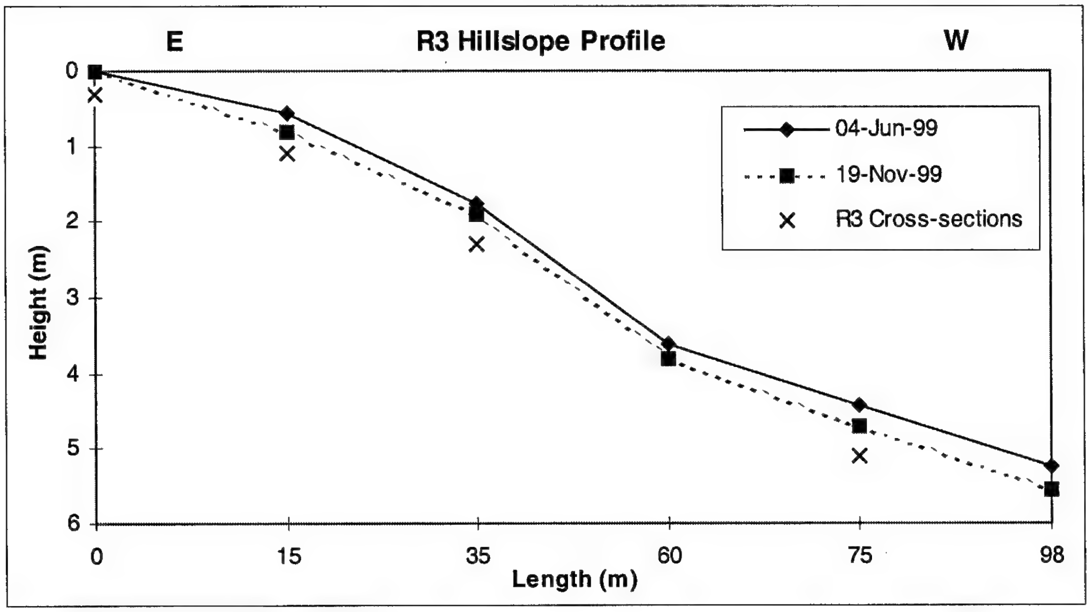



**Figure 3-7. R3 Right Center-line Profile Survey**

The WEPP Hillslope model was run with a one-year simulation to simulate soil erosion and to compare results with the field measurements of the R3 profile. These preliminary modeling results are intended to analyze a general trend for this hillslope using basic model parameters of management practices, slope profile, soil profile, and regional climate generators. The model results were similar to the observed general trend of detachment and profile lowering along the entire length with no deposition (Figure 3.9) but modeled a lower rate of erosion at 0.85 $kg/m^2/yr$ or 0.35 $kg/m^2/(5\ months)$ as compared to the R3 cross-section soil loss rate (15.68 $kg/m^2/(5\ months)$) (Table 3-2).

| R3 WEPP Results | |
|---|---|
| Management | Range-Graze |
| Soil Name | Vaucluse |
| Average Annual Precip(mm) | 1160.90 |
| Average Annual Runoff (mm) | 260.30 |
| Average Annual Soil Loss (kg/m2) | 0.85 |
| Detachment Length (m) | 98.00 |
| Average Deposition (t/ha) | 0.00 |
| Deposition Length (m) | 0.00 |

**Table 3-2. R3 Profile WEPP Model Results**

Limitations of this simulation include the lack of available management parameters for the WEPP model for Mill Creek conditions. For example, there are no parameters for road surfaces or the Vaucluse soil profile. Use of this model in forested areas with timbering practices therefore, required some generalization and manipulation of available parameters in this area. Past WEPP model validations have indicated that rangeland interrill erodibility values were underpredicted and rill erodibility values were overpredicted. Although these errors were not as much as with cropland values used on recently graded forest roads, caution is advised when utilizing this model outside agricultural areas (Elliot et al., 1995). A bare rangeland management practice was constructed to match the dirt road profile. A Vaucluse soil profile was built from field measurements to reflect the change caused by grading in the county Vaucluse soil profile. The field-surveyed length-slope values of the profile and the WEPP regional climate data from Aiken, SC were used in the simulation. This model will require more in-depth parameterization and field analysis to better represent the local physical properties and management practices if used as a prediction and management tool. Given the

substitution of surrogate climate, land-use, and soil parameters, greater credence is given to the spatial location of model results than to the absolute magnitude of erosion.

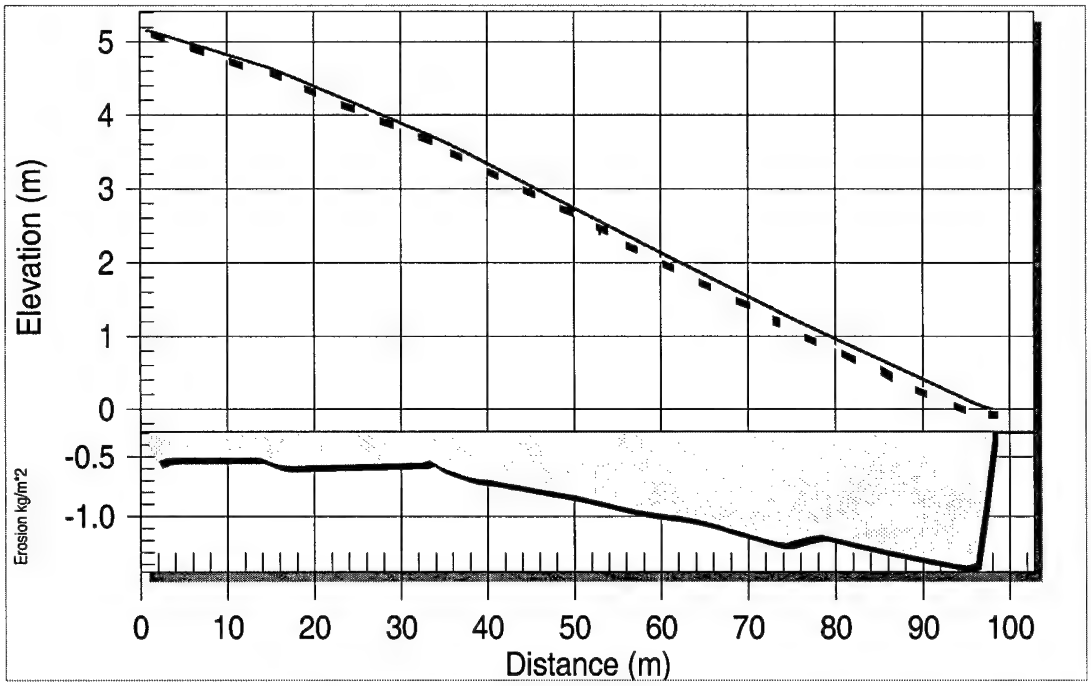



**Figure 3-8. Preliminary WEPP Hillslope Profile Model Graphical Results. Top curves: Initial Profile Being the Solid Line and the Predicted Profile as the Dotted Line and Bottom Profile predicting the Soil Loss Rate along the Profile**

The WEPP hillslope model outputs a display of the dirt road initial profile with the solid line and the resulting profile after the one-year simulation with the dotted line (Figure 3-9). The trend of continuous soil loss is reflected in the model with the reduction in elevation along the profile. The bottom portion of the soil loss graph indicates the change in erosional rates along the profile. The maximum rate occurred around 95 m down-slope. The rapid decline of the erosion rate from the maximum point to the segment end at 98 m implies that deposition may start to occur soon after this point.

This would be consistent with field observations at the site. Beyond the 98m point of this profile, the hillslope changes gradient as it intersects two other dirt roads and is only three meters from the forest woodline. The WEPP corroborates the lower erosion rates observed at the uppermost cross-section where there is less runoff. The highest erosion rates occur near the slope base at the greater slope lengths where the runoff reaches maximum volumes and velocities and has the greatest detachment potential. Beyond 96 m the breaks in slope and increased infiltration into recent sandy deposits decrease the sediment transport capacity and result in further deposition.

*R2 Gully Profile*

The R2 gully erosion site was different than the R3 hillslope site in that was an established rill on which road runoff was actively maintained (Figure 2-8). There was no dominant erosion-susceptible area within the gully and for the most part observed sediment movement across the channel was uniform. The R2 segment five-month soil loss was 1.42 $kg/m^2$ based on the product of the soil loss area (0.21 $m^2$) and the distance between cross-sections (2.6 m) divided by the segment area 5.89 $m^2$. This soil loss is greater than that of R3 and is representative of the erosive potential of rill erosion over loose sediment. As with the R3 hillslope, the R2 gully had a change of gradient as it left the road and entered the forest wood-line. Unlike the R3 hillslope site, the R2 gradient increased to 6 percent. This resulted in a long sediment plume that had a length of 78.5 meters as measured from the forest edge.

**<u>Interill Small Box Plots</u>**

The small box plot sediment from the 2-foot by 2-foot wooden boxes indicate soil susceptibility to entrainment forces by raindrop splash and sheet erosion. Evidence of

splash erosion could be seen on the sides of the box with negligible sediment on the tops of board walls. This indicates that little sediment is being splashed into or out of the box but could represent some losses or at least a lag in sediment reaching the box drain spout. This error, described in Lal (1994) as the *edge effect*, was minimized by ensuring similar ground conditions surrounded the boxes. Eleven box sample plots were maintained from mid-June 1999 to mid-September 1999 for five storm events. Increased vehicular traffic and human activity in the study area compromised the boxes after September 1999. Five control boxes were established in representative forested areas and six test boxes were established on dirt roads. The dirt road unit sediment loss ($kg/m^2$) means were hypothesized to be significantly higher than the forested control group. The dirt road sediment means were tested and found to be significantly greater than forested sediment at the 0.05 alpha level (t-Stat = 2.3152 and P ($T \leq t$) = 0.0342) (Figure 3-2).

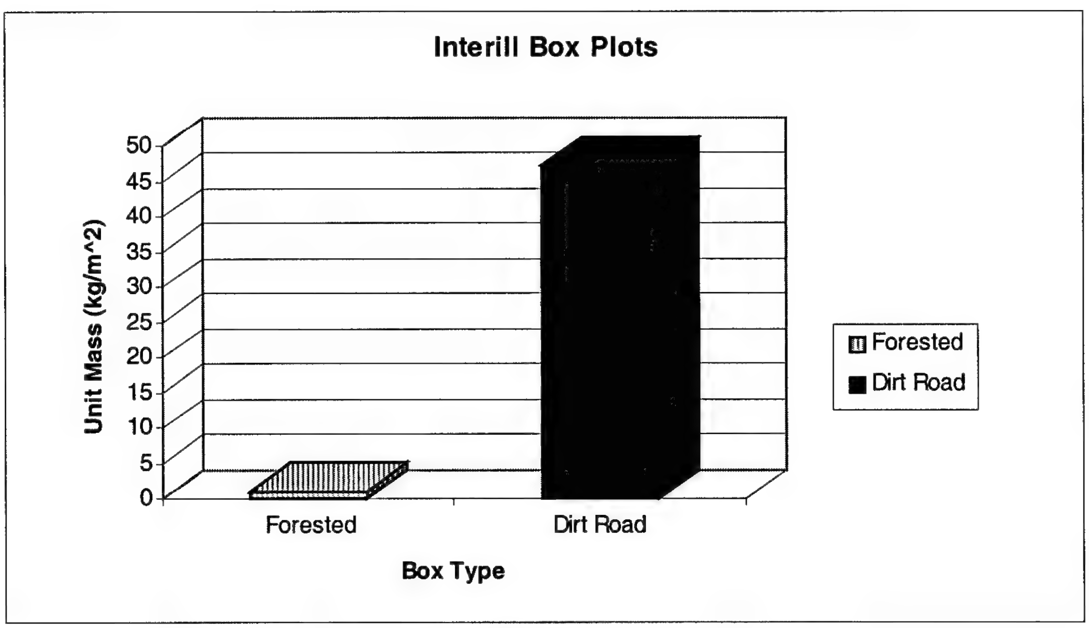



**Figure 3-9. Interrill Box Plot Mean Unit Mass**

### *DEPOSITION*

Sediment deposition was noted at several locations within the study area. Deposition was observed mainly at locations where road runoff entered the forest edge. Additionally, deposition occurred on road slopes where decreases in gradient reduce flow energies. Two other areas of deposition were within the wetland and along channel beds. In the wetlands, evidence of fines coating the litter layer was observed as a result of inundation and overbank flow. Within the ditched channels of W1E and W1N, some temporary sediment deposition occurred but for the most part the channels remained clear as the thin veneer of bed sediment was removed with subsequent storms. One exception was the W1E tributary draining the BRM-19 rifle range, which remained filled with sandy sediment. Field observations of changes in morphology of the channel sand deposits indicate these bed materials were moving during storms. Another exception is on the W1E channel below the confluence with this BRM-19 tributary, where the ditch morphology is observed by channel aggradation. The wide shallow channel in this reach indicates sediment storage in the main channel.

Considerable sediment storage also occurs below roads in the transition zone at the wetland margins. Buffer zone deposition efficiency was evaluated by measuring the reduction of sediment being transported through the transition zone between sediment sources (a gully) at the road edge and the wetlands toward the channel. This transition zone acts as a buffer zone as flow velocities are reduced upon entering the gentle slopes of the vegetated wetland. The unit weight ($kg/m^2$) of sediment deposition was measured on five occasions over a six-month period. Transects were sampled at five different locations with less than a 3 percent slope (Figure 2-9). Each, sampling consisted of four

mats along a transect at ten meter intervals. The unit weights along each of the five mat transects indicate that a large portion of the sediment was trapped in the first 10 m of the buffer zone with a exponential decline reaching a minimum around 30 m and an slight increase in deposition at the 40 m width (Figure 3-10). This indicates that the majority of deposition occurred in the first portion of the buffer zone but occasional flooding near the channel presumably caused the slight increase at the 40 m position by overbank suspended sediment or slackwater conditions. This sedimentation from slackwater or overbank flow may not be applicable on hillslope transect away from channels or wetlands. The mean unit mass deposited at the first 10 m buffer width was significantly greater than the combined mean deposition weights at the other three sites at the 0.05 alpha level (t-Stat = 2.27 and P (T<=t) is 0.04). Thus, buffer widths from 20 m to 40 m would be far less effective at trapping sediment than the narrow strips, based on these samples. Increased runoff during larger flows, less vegetation, and areas of steeper slopes may have different results.

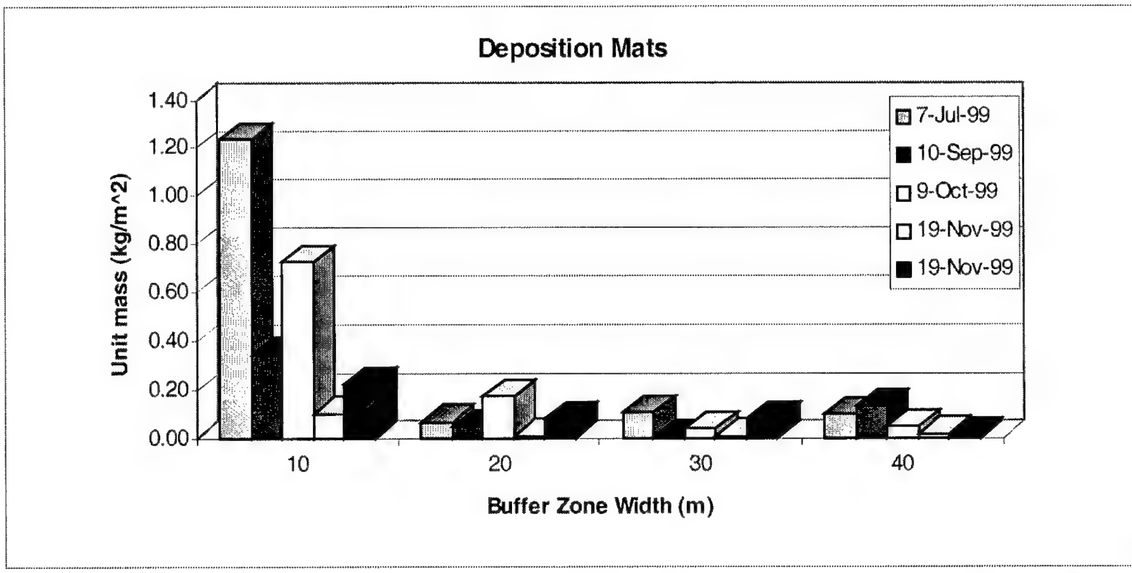



**Figure 3-10. Sediment Deposition on Mats Occurred mostly Near the Edge of the Wetland. Each Storm was Measured at a Different Transect of Four Mats**

A statistical regression of the unit mass against transect distance explains 70% of the variance in sediment deposition (Figure 3-11). At the 30 m buffer width, the statistical model predicts sediment deposition is essentially zero (-0.02). Due to increased sedimentation caused by inundation near main channels in the wetlands, the 40 m buffer width may not be necessary in this environment for this size runoff events if an insignificant amount of sediment is being transported past the 30 m width. However, if continued long-term deposition causes steeper gradients that may result in sediment being transported further into the buffer zone.

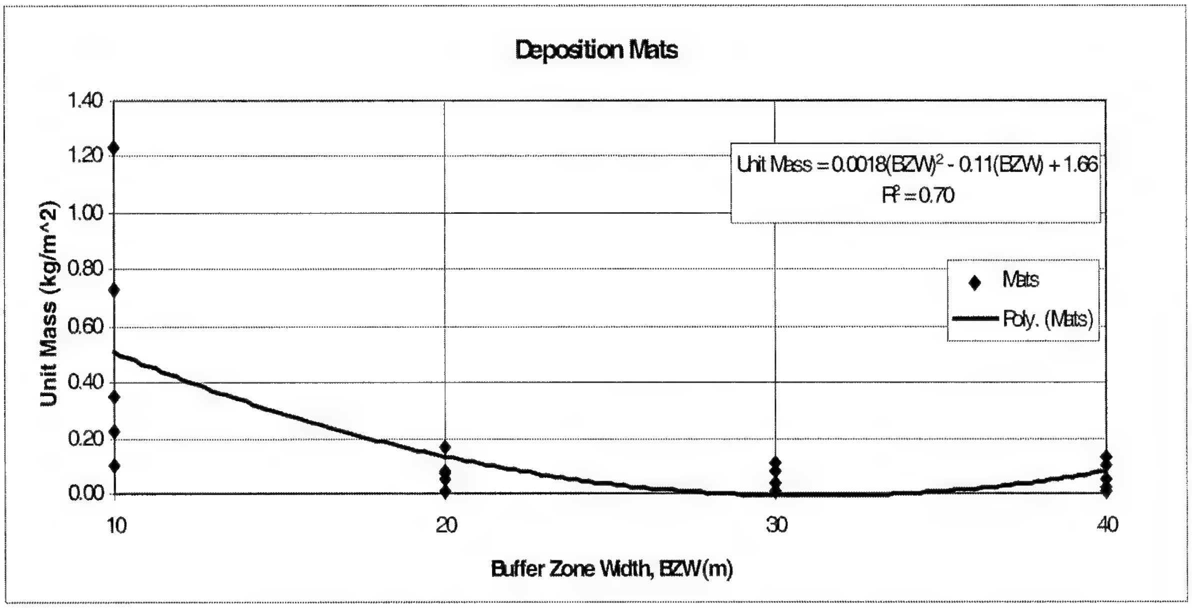



**Figure 3-11. Sediment Deposition as a Function of Distance along a Transect**

Deposition mat particle textural analysis reinforced the unit mass findings. Statistical averages of loss-on-ignition (LOI) and sediment textures from wet sieving for twenty mat samples are shown in Figure 3-12 as percent weight. These sedimentologic results show that the greatest percentage of sand is deposited in the 10 m buffer width along with the least percentage of fines or organics. This indicates that the larger sand particles are settling out quickly with the increased roughness and decreased slope. The fine sediment is being transported further along the transect. There is also an increase in organic matter as the runoff mobilizes the litter layer. The little change in texture or organics between the 30 m and 40 m buffer widths may reflect deposition dominated by over-bank inundation near the main channel of the east tributary.

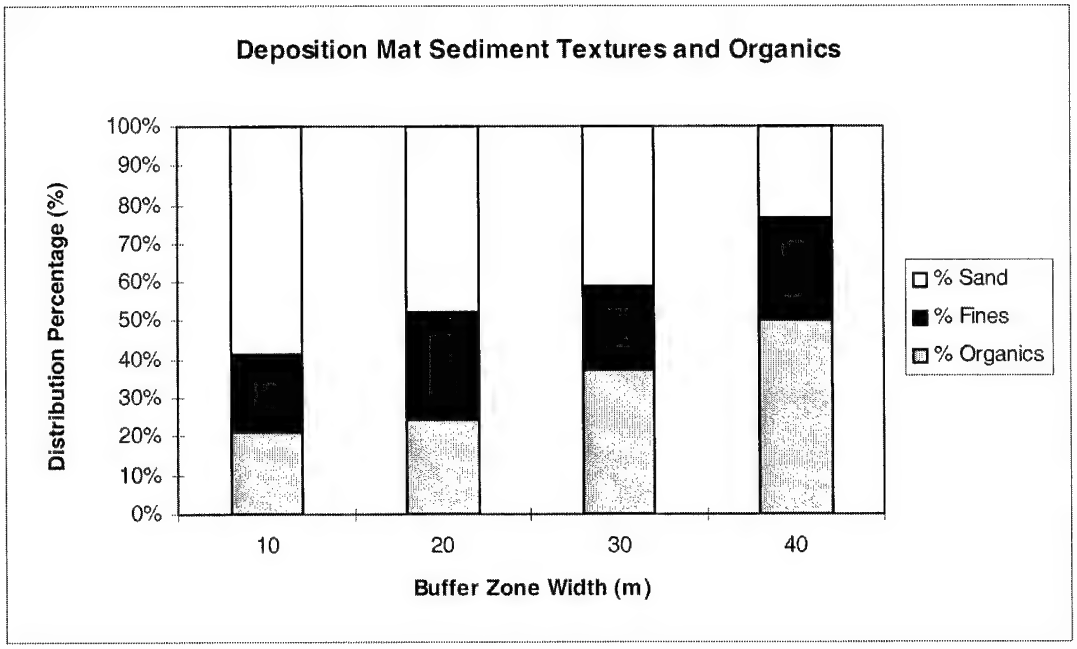



**Figure 3-12. Deposition Mat LOI and Wet-Sieving Results (Percentages by Weight) Values at each Horizontal Position are an Average of Five Events at that Site**

Sand distributions also reflect deposition along the transect. Sand textures measured by sonic-sieving are shown in Figure 3-13. The coarser sands (> 0.5mm) generally decrease with an increase in buffer width. This fining away from the source is also reflected in the distribution of the fine and very fine sand particles (<0.25mm and >0.63mm). There is a sharp increase in the fine and very fine sand particles with the increase in buffer width reaching a peak at the 30 m width. Typically, this distribution indicates that deposition is occurring in the lower velocity flow environments after the larger particles had settled. Very little material coarser than sand (> 2mm) was being transported. One large pebble was found in a 30 m sample and may indicate scour of an erosional lag from an adjacent surface. Presence of coarser particles may reflect substantial distances of sediment transport in large storm events. Therefore, these results

conclude that sediment deposition is substantially reduced with distance traveled across a buffer zone transect.

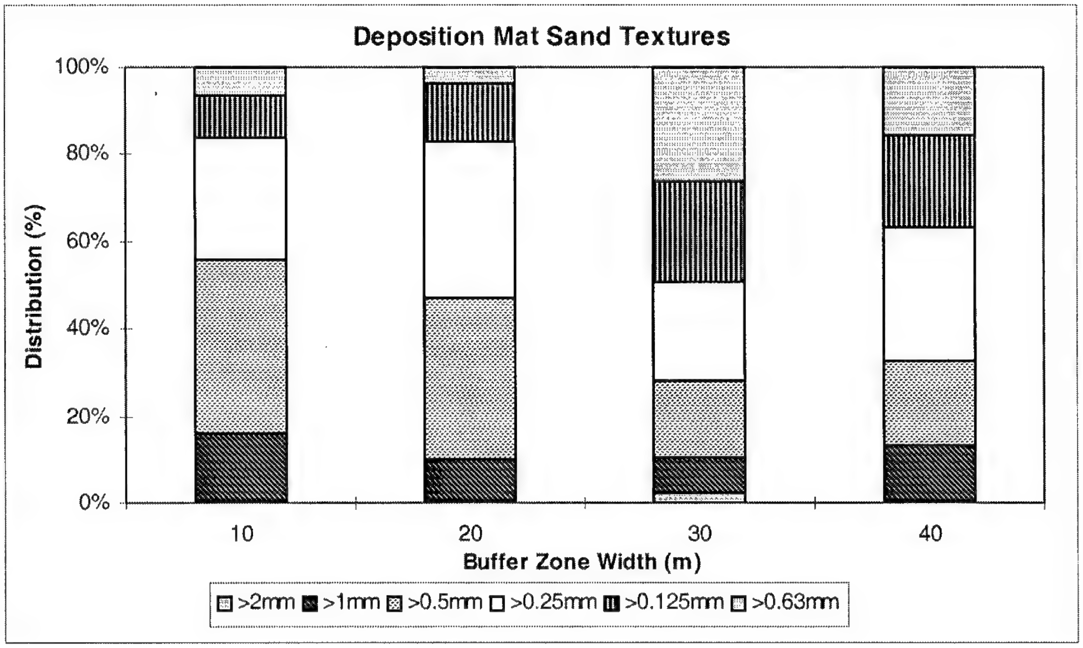



**Figure 3-13. Sand Textures of Sediment on Deposition Mat after Removal of Fines and Organics**

## SEDIMENT YIELD

This section addresses several factors that contribute to sediment yield. Topics include discharge, suspended sediment concentrations, suspended sediment storm flux, hysteresis, and study area land-use changes.

### Discharge

Nine discharge readings were taken at gage 7 on W1E in order to establish a stage-discharge relationship and functionalize discharge (Figure 2-3 and Table 2-2). A second-order polynomial had a high explained variance ($R^2 = 0.98$). Residual analysis had no indication of change through time for the discharge measurement period of June

through September. Statistical inferences utilizing a confidence interval of 95% indicates an accuracy of $\pm$ 1.59 (l/s). Manual staff gage readings and continuous stage recorders monitored discharge. A statistical regression of manual staff gage readings functionalized the continuous fifteen-minute recordings of mV values provided an expression for stage as a function of logger output ($R^2$ of 0.95).

The variance was a result of limited staff gage readings, the $\pm$ 1 cm margin of error in the pressure transducers used, and the variance caused by the fifteen minute time interval. The function allowed the conversion of logger mV values to gage heights values and subsequently into discharge values by applying the stage discharge function in (Figure 2-3). Equipment failures resulted in a period of lost data prior to June and after late December 1999.

A preliminary continuous discharge record for this period was obtained and utilized in examining the discharge data prior to and after the visual staff readings to gain general insight into storm events response. Since further data collection is needed to gain a better relationship between continuous logger readings, staff gage heights, and discharge, greater credence was given to manual staff gage readings in the calculation of discharge. Instantaneous discharge calculations for corresponding suspended sediment samples allowed further application with suspended sediment flux. Hydrographs were constructed to depict the arrival and timing of discharge peaks and allow calculation of storm discharge (e.g. Figure 3-14).

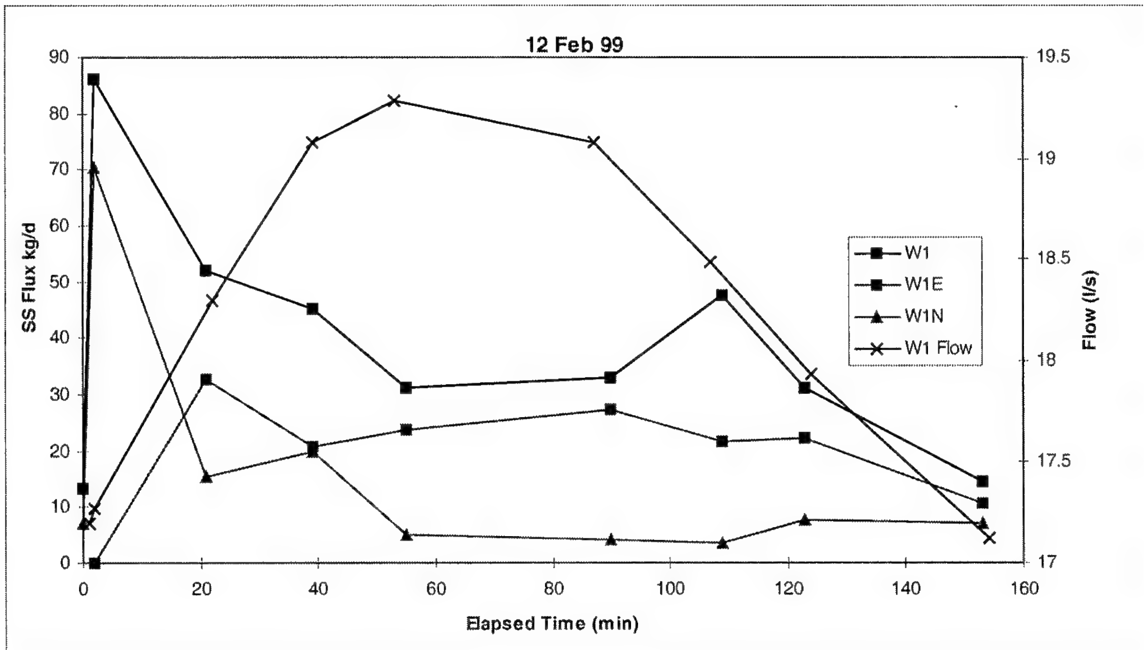



**Figure 3-14. Single Storm Runoff Hydrograph for 12 February 1999 with Suspended Sediment Flux at the three Gages. Note the Early Arrival of high Sediment Fluxes at W1N and W1**

Base flow was separated from storm flow for five storm events by applying a method for basins less than 20 square miles. A straight line was drawn from the initial point of rise at a rate of 0.05 cfs per square mile per hour (Hewlett and Hibbert, 1967). Instantaneous storm flows were calculated by subtracting base flow from the total discharge. For the total storm runoff, the area under the curves for W1, W1E, and W1N was calculated as the sum of the products of instantaneous flows and their respective duration (Figure 3-14).

## Suspended Sediment Flux

The calculated total suspended sediment flux for an individual storm provides the sediment yield for that event at the three gage sites to test for differences between W1E and W1N. Total sediment storm flux and discharge magnitudes were calculated for five 1999 events (12 Feb 99, 16 Jun 99, 19 Jul 99, 4 Oct 99, and 10 Jan 00) (Table 3-3). Due to differences between 1997 and 1998 sediment concentrations discussed later, no attempt was made to compare sediment fluxes between W1N and W1E for the earlier period.

| | Total Storm Sediment Flux (kg) | | | |
|---|---|---|---|---|
| Total Q (m3) | W1 | W1E | W1N | Date |
| 11.4 | 5.2 | 3.53 | 1.68 | 12-Feb-99 |
| 78.5 | 117.2 | 47.7 | 69.5 | 16-Jun-99 |
| 4.3 | 19.2 | 1 | 18.2 | 19-Jul-99 |
| 9.9 | 0.068 | 0.679 | 2.19 | 4-Oct-99 |
| 3207.8 | 633.2 | 392.7 | 240.5 | 10-Jan-00 |

**Table 3-3. Selected Storm Flux and Discharge Totals**

Field observations indicated sediment concentrations came in pulses at varying time intervals from the two tributaries. W1N tended to peak ten to fifteen minutes from the centroid of precipitation. In response to quick intense storms with low discharge, like 12 July 1999, W1N peaked at five minutes with a peak suspended sediment concentration of 2000 mg/l. W1E had little sediment response to this storm with a peak suspended sediment concentration of only 71 mg/l. The maximum rainfall intensity for 19 July 1999 was 0.84 mm/minute and a total precipitation of 11.2 mm. With a low-intensity storm such as 4 October 1999, W1N responded with a high suspended sediment peak

concentration of 371 mg/l about fifteen minutes after the precipitation centroid. During this low-intensity storm event, the sediment pulse in W1E was delayed about 45 minutes past the precipitation centroid and had a maximum suspended sediment concentration of 21 mg/l. The main difference in the storm events was that the later storm had a lower rainfall intensity (0.25 mm per minute) than the first storm. The sediment concentration differences between these two storms reflect the erosive potential of high intensity storm events.

Sediment contributions from the W1E or W1N tributaries do not provide constant proportions of the total sediment load. Generally, W1N is the main contributor to storm flux in short intense convectional storms. In the longer duration frontal storms, W1E contributed the most sediment. The mean sediment fluxes for these five storm events were tested to see if there was significant difference between the two tributaries. No significant difference in sediment flux was found between the two channels at the 0.05 alpha with (t-Stat = 0.69 and P (T<=t) = 0.53). Since W1N tends to contribute high amounts of sediment during the shorter events, the small storm means were tested separately and again there was no significant difference at the 0.05 alpha level with (t-Stat = 1.67 and P(T<=t) = 0.19).

The assumption of equation two, ($Qs_{W1} = Qs_{W1N} + Qs_{W1E}$), is that the sediment discharge of the main channel is the sum of the suspended sediment discharge of the two tributaryes immediately upstream. This assumption was tested using a t-test on the sediment discharges for W1 verses W1N and W1E. Using samples taken at each of the three sites at no more than three minutes apart, the sediment flux of the main channel was found to have no significant difference from the sum of the north and east channels at the

0.05 alpha level (t-stat = 0.80; P = 0.43). This test confirms that contributing discharge and suspended sediment load at W1N can be calculated with reasonable accuracy by measuring water and sediment discharges in the main channel and the east tributary.

To chart a general relationship between sediment flux and discharge the storm flux data were plotted against the log of storm discharge (Figure 3-15). The results indicate a general rise of storm flux with storm discharge but considerable scatter. Storm flux and storm discharge was also evaluated against maximum precipitation intensity and total rainfall depth. Sediment load varied erratically with rainfall intensity but there is the suggestion that rainfall intensities are associated with higher sediment fluxes in the north tributary than in the east tributary (Figure 3-16). A sharp increase in sediment flux occurs with total rainfall suggesting, as expected, that more sediment is moved by larger events (Figure 3-17). The high variability in sediment flux with discharge, precipitation intensity, and precipitation totals call for a more thorough examination of the relationship between sediment concentration and runoff.

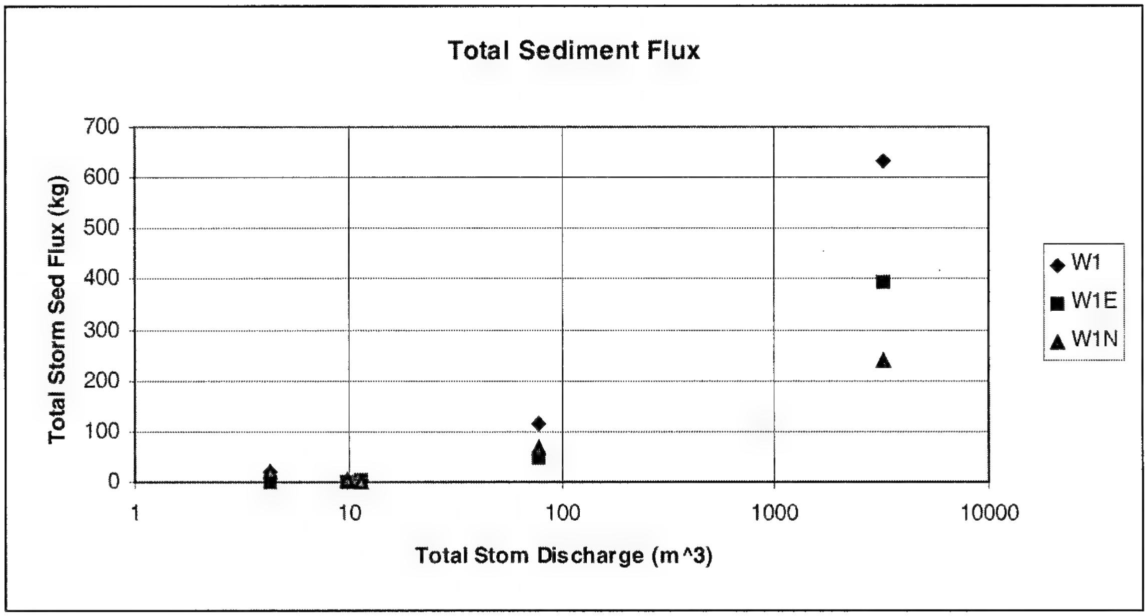



**Figure 3-15. Storm sediment Flux and Storm Discharge Totals (Same storm events in Table 3-3)**

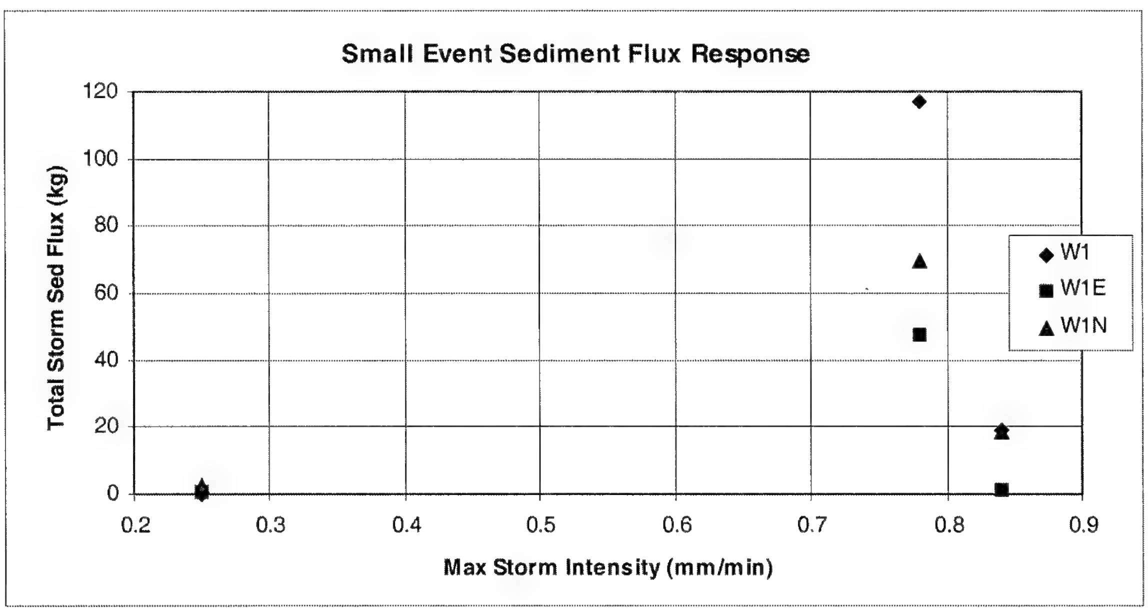



**Figure 3-16. Storm Flux Response to Max Rainfall Intensity (Same storm events in Table 3-3)**

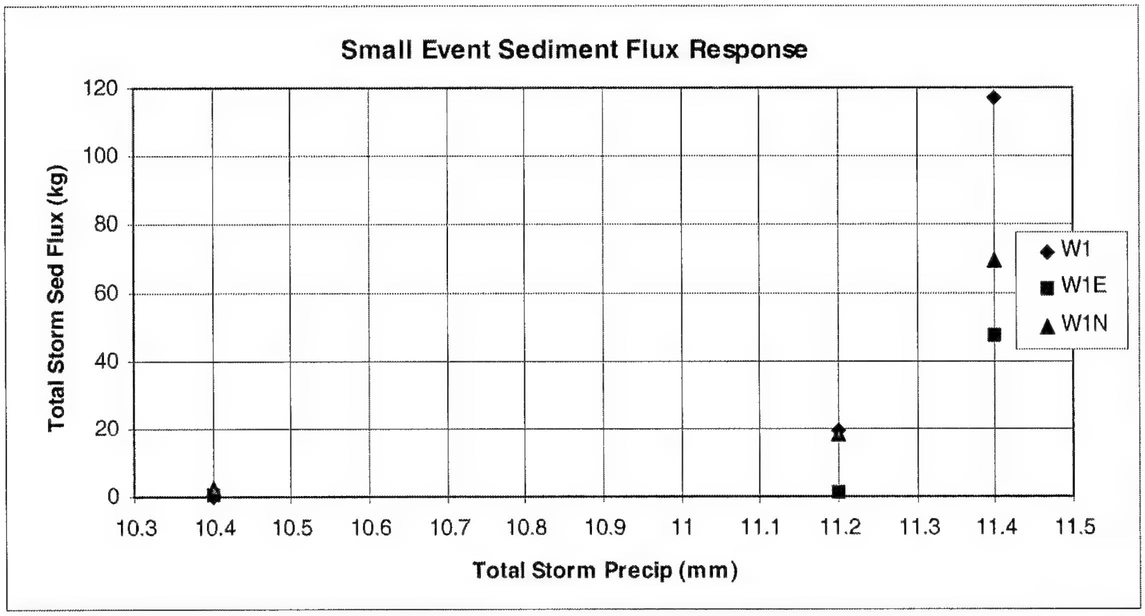



**Figure 3-17. Storm Flux Responses to total Precipitation (Same storm events in Table 3-3)**

## Suspended Sediment Concentrations and Rating Curves

Calculated as the product of measured suspended sediment concentrations of W1, W1N, and W1E and their respective flow discharges. Suspended sediment concentrations were highly variable due to fluctuations in the timing of pulses of discharge and sediment coming from each tributary. Suspended sediment concentration data tables are found in Tables D1 through D12, (Appendix D). Basic suspended sediment concentration statistics reflect the wide range of concentrations (Table 3-4).

| Gage Site | Min | Max | Mean | Std Dev | N |
|---|---|---|---|---|---|
| W1N (G6) | 6.10 | 2529.41 | 284.03 | 531.98 | 55 |
| W1E (G7) | 6.33 | 394.74 | 83.51 | 95.80 | 56 |
| W1 (G1) | 6.54 | 1181.82 | 126.67 | 172.78 | 60 |

**Table 3-4. Basic Statistics of 1999 Suspended Sediment Concentration (mg/l) by Sampling Site**

In order to expand this study's results with other studies of the watershed, several suspended sediment-rating curves were developed to analyze sediment response to discharge under different conditions. These rating curves relate instantaneous (single sample) sediment concentration measurements to the corresponding streamflow delivered from the stage observations. Both suspended sediment concentrations and unit flux rating curves allow comparison between the two subbasins of the north and east tributaries. Stratification of data was necessary to gain insight into sediment responses. Extensive land-use changes and an unusually low rainfall allowed examination of responses to these changes.

*Comparison with Previous Studies*

A large number of suspended sediment samples were collected and processed between 1997 and 1998 (Dean et al., 1998; 2000). Analysis of covariance with the W1 data between 1997-98 and 1999 indicate significant difference is evident (Figure 3-18). Statistically, the 1999 data have significantly higher sediment concentrations than the earlier data at the 0.05 alpha level with a (F= 26.48 and P (>F = 0.0001). This may be a result of changes in land use, particularly the increased logging activity and road work, or drought conditions which allow an increase in loose sediment particles to accumulate between storm events. Due to this significant difference in sediment rating curves, the

1997 and 1998 data were not included in further analysis of the W1 sediment data collected by this study.

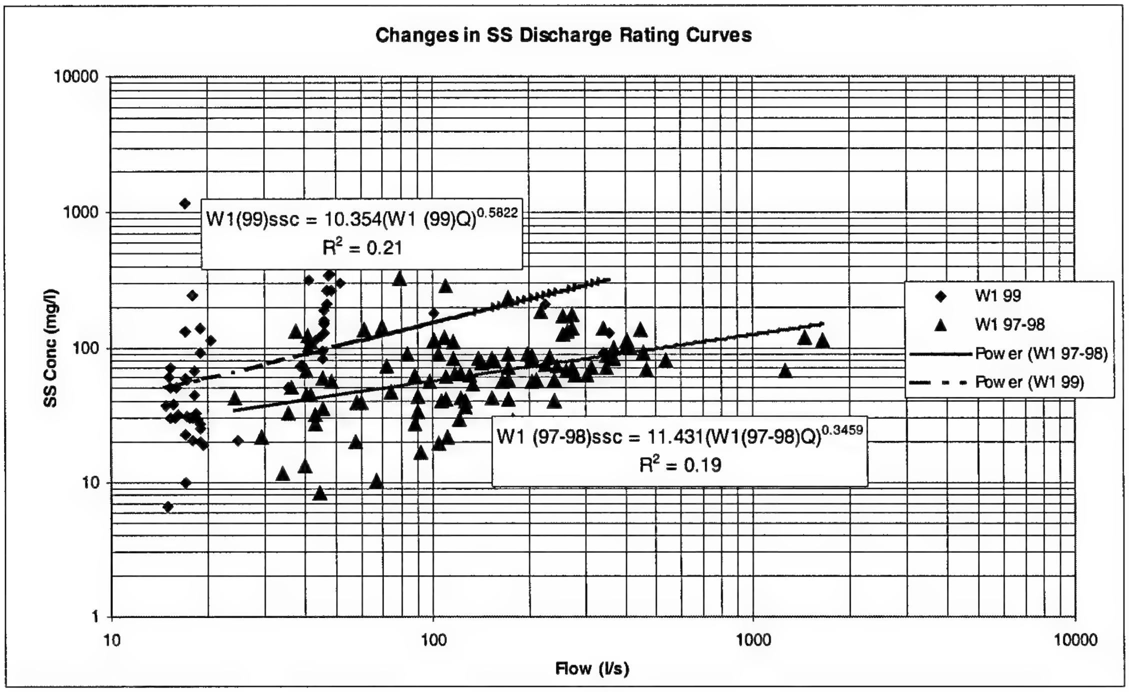



**Figure 3-18. W1 suspended Sediment Concentration Data from 1997-98-99 as Functions of Discharge.**

*Stratified 1999 Sediment Rating Curves*

The 1999 sediment concentration data were split into W1 and W1E data series. This allowed for comparisons of the two tributaries with the inference that any differences resulted from the W1N tributary contributions to W1. The total W1 sediment rating curves show a high degree of variability in sediment concentration with discharge (Figure 3-19). Although regression equations are presented, the high unexplained

variance limits their utility for long-term sediment flux calculations and calls for stratification of the 1999 data (Figure 3-19).

Several approaches were taken to systematically examine the data for possible reasons for the high variance and improve the understanding of the W1 watershed sediment responses to discharge. The first approach was to separate data based on rising verses falling limbs of the hydrograph. The peak discharge reading was included in the rising limb. The next stratification was a seasonal separation of the data. In this watershed, the storms were mainly convectional events from April through September and were more typically frontal storms from October through May. There were no major precipitation contributions from hurricane events during this study.

The rising versus falling limb stratification resulted in an improved relation in the falling limb rating curve ($R^2$ =0.44) but had a higher variability ($R^2 = 0.11$) in the rising limb rating curves especially in the W1 data as a result of W1N contributions. The arrival of the first flush of suspended sediment in W1N explains the weak rising limb relationships.

The quick response times to runoff in this small watershed commonly results in multiple pulses of sediment, an early pulse (first flush), and bimodal peaks due to variability of rainfall intensities during storm events. All of these factors are present in the study area. Response times vary between the W1E and the W1E tributaryes complicating the suspended sediment concentration in the W1 main channel.

The W1N site is greatly influenced by the first flush phenomenon. The peak sediment concentrations arrive very early within five to ten minutes of the centroid of precipitation and with intense storms within a five to ten minutes of the start of the

precipitation. In this initial period, the concentration is spiked with a pulse of suspended sediment moving down the W1N tributary. The concentration peaks early in the rising limb and then begins to decrease as the discharge continues to rise. During longer events, there may be a second pulse from W1N as sediment from further upstream arrives and the first flush sediment has been removed. The second peak is high as the first flush. As a result of the first flush phenomenon W1 suspended sediment concentrations are highly variable with discharge ($R^2 = 0.11$) during the first fifteen minutes from the centriod of the precipitation.

Analysis of precipitation data and field observations suspended sediment concentration arrivals reflected this quick response from W1N. The fast increase of suspended sediment came from direct road runoff that enters W1N about 50m upstream from the sampling site (Dean et al., 1998; 2000). To isolate the random error associated with this first flush, the first fifteen minutes of each storm (measured from the centroid of precipitation) was separated from other sediment concentration measurements. After removal of these early data points, the variance in sediment concentration as explained by discharge increased substantially to $R^2 = 0.37$ (Figure 3-20). Comparisons of figures 31-19 and 3-20 reveal that removal of the first fifeteen minutes of the hydrographs had little effect on W1E rating curves ($R^2$ increased to 0.32) but removed some anomelously high suspended sediment points associated with moderate discharges on W1N raising the $R^2$ from 0.21 to 0.37.

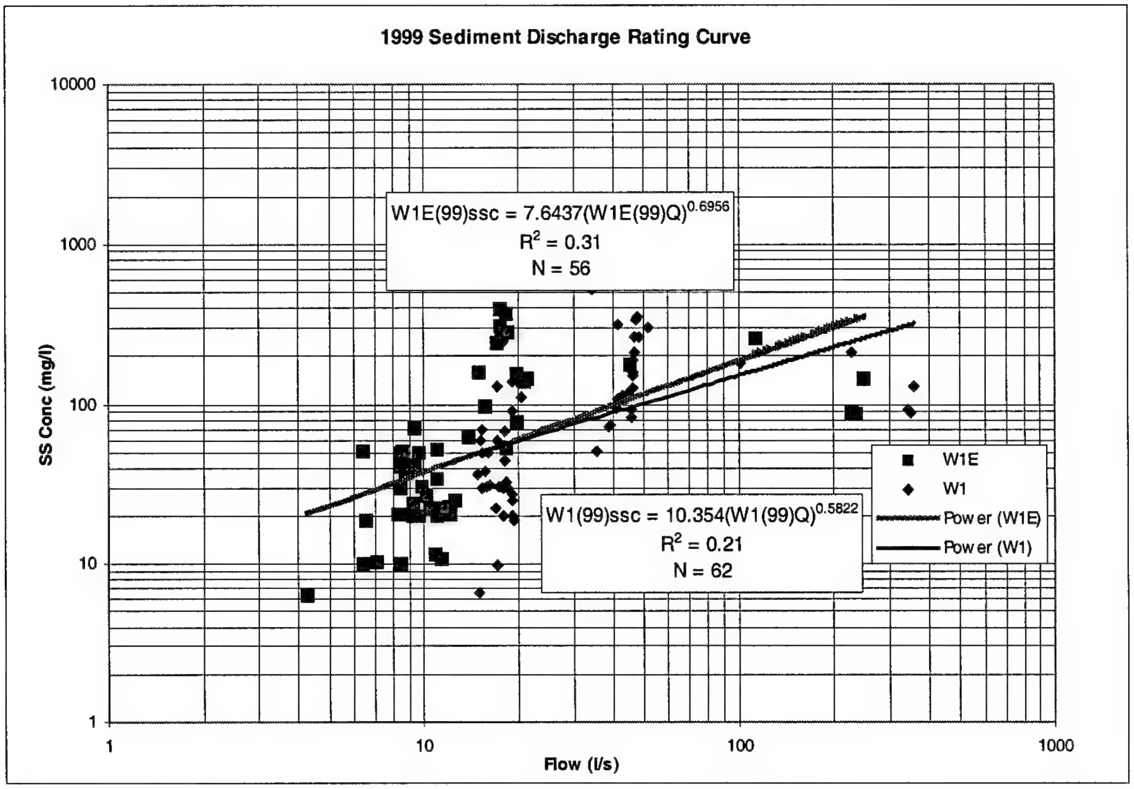



**Figure 3-19. 1999 W1 and W1E Sediment Rating Curves for entire Hydrographs (All Data).**

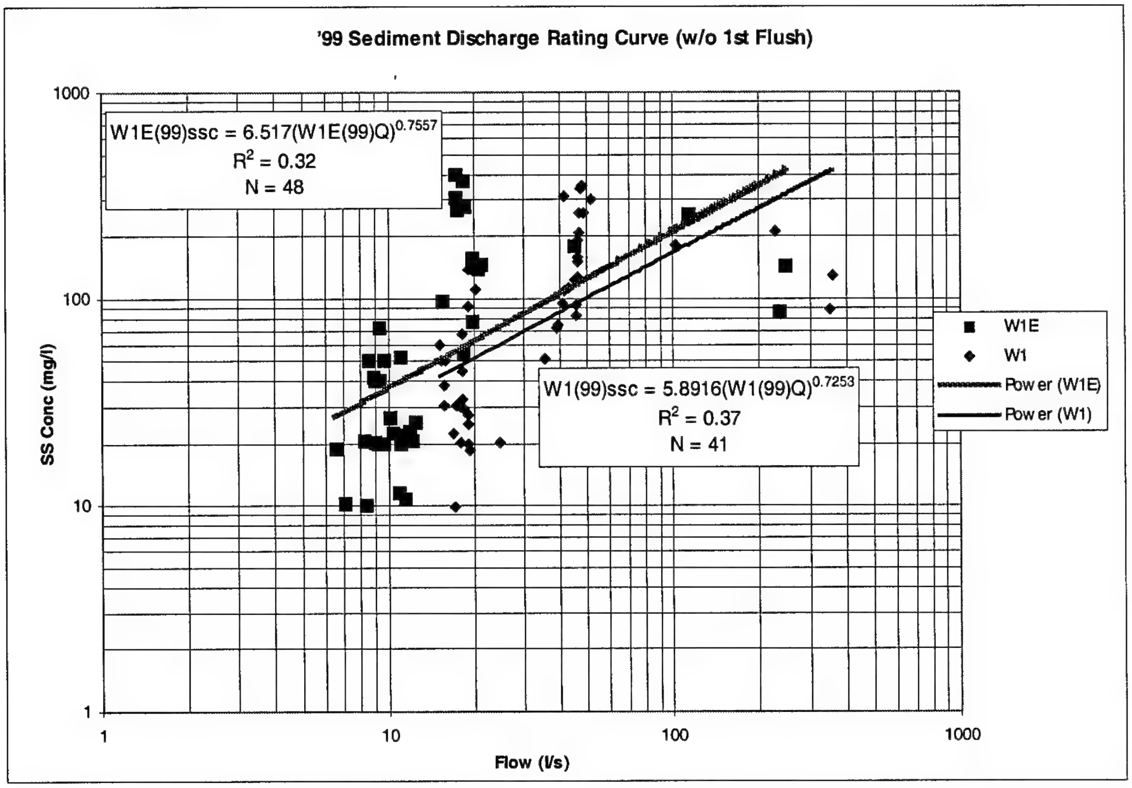



**Figure 3-20. 1999 W1 and W1E Sediment Rating Curves without First Flush**

Seasonal differences in observed sediment concentrations suggest that seasonal stratification may further improve the rating curves. For this analysis the entire 1999 W1 sediment concentration data were split into summer (April through September) and winter (October through March) samples. The results of this stratification improved the variability even more and suggest that the summer convectional storms with short duration and high intensities are associated with high variability in suspended sediment concentrations ($R^2 = 0.38$) (Figure 3-21). The winter storms sediment concentrations can be approximated with discharge with a reasonable accuracy ($R^2 = 0.54$). Interpretation of

these apparent seasonal effects is complicated by changes in land-use and is discussed in a later section.

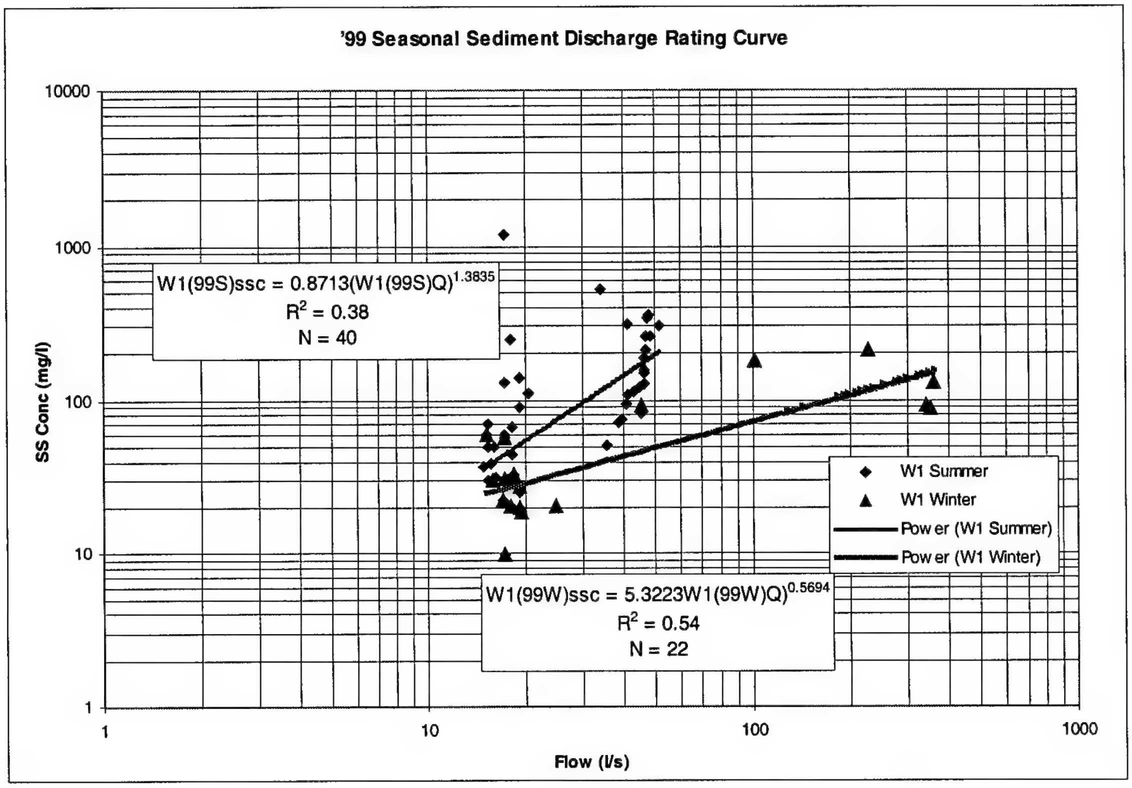



**Figure 3-21. W1 Seasonal Rating Curve**

**(Including both Rising and Falling Limbs)**

Finally, a logical step was to see if removing the first flush from the seasonal rating curves would yield good rating curves and reduce variability to the seasonal stratification. For winter storms, however, this was done by removing the data points from the first fifteen minutes following the precipitation centroid. The results for summer storms were substantially improved from 0.38 to 0.54 explanation of variance (Figure 3-22).

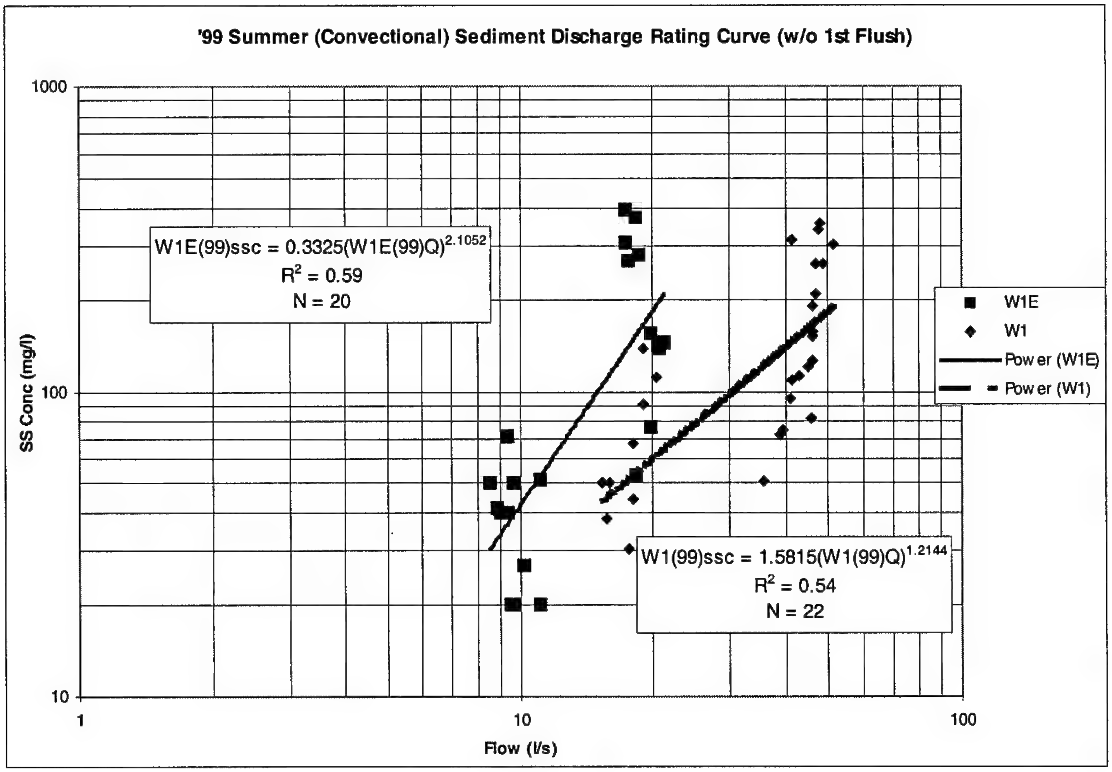



**Figure 3-22. W1 Summer Rating Curve without First Flush**

Not much improvement for winter data with the removal of the first flush data points as evident with an increase of only 6 percent in $R^2$. Winter stratification is sufficient and little is gained by the first flush stratification. Reduction of summer variability due to the first flush data was substantial with an increase of $R^2$ from 0.38 to 0.54 and resulted in an improved association of sediment concentration as explained by discharge. Therefore, seasonal stratification and the removal of the first flush data points yield an improved the summer suspended sediment concentration.

## Hysteresis

In an attempt to identify process-related sediment dynamics for the system, the timing of sediment deliveries was further analyzed. This timing can be expressed as

"hysteresis." Hysteresis is the systematic direction in which a dependent variable varies from a regression line when sequence of values are examined (James, 1998). Due to the strong first flush of sediment, sediment concentrations in W1N typically display a spiked-clockwise hysteresis (Figure 3-23). It is this spike within the first fifteen minutes that is most difficult to characterize with sediment rating curves. Although subsequent suspended sediment concentrations remain hysteric, the error they impart is relatively minor (e.g. points between 26 and 31 l/s on Figure 3-23).

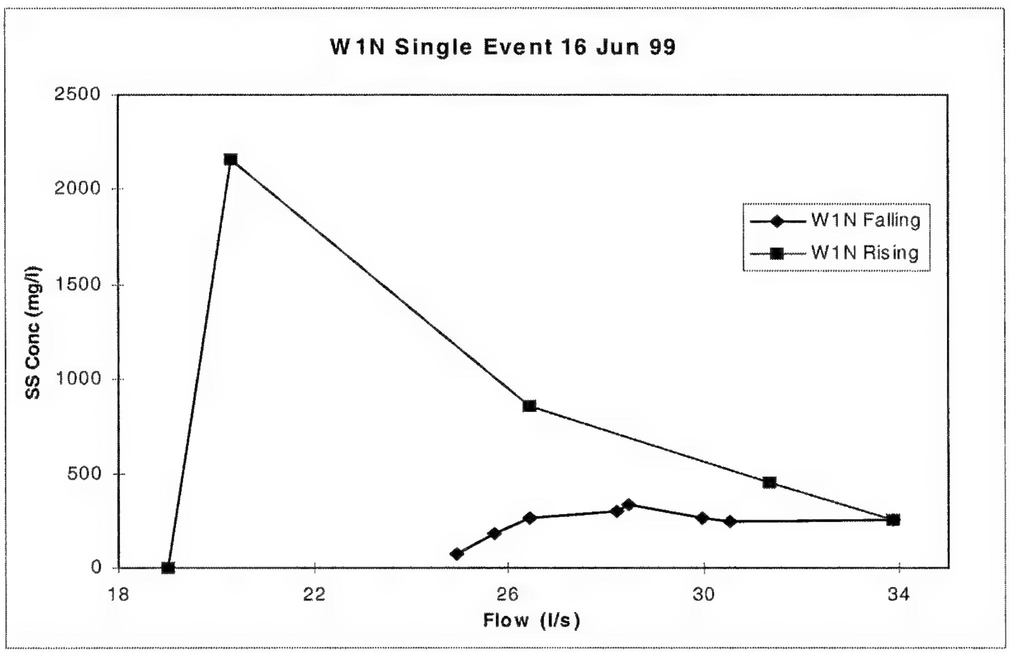



**Figure 3-23. W1N Typical Clockwise Hysteresis**

W1E has a different timing of suspended sediment concentration than W1N. W1E does not have the quick pulse of sediment like W1N but has a slower response in sediment concentration and discharge due to the distance of the channels from the roads. Generally, the W1E sediment concentration peak occurs around an hour after the precipitation centroid. W1E's sediment concentration generally peaks before or shortly

after the discharge peak. This is illustrated in the response on 16 June 1999 where the sediment concentration peaked on the rising limb of discharge giving a clockwise hysteresis with the spike later than in W1N (Figure 3-24). For storms where W1E suspended sediment peaks after peak discharge, a counter clockwise hysteresis results with the spike occurring closer to peak discharge. W1E has varied seasonal response. With the quick summer storms, the sediment concentration response was about 45 minutes after the precipitation centroid and the winter storms had about a 75-minute delay. This could be due to storm type and the increased winter ground litter.

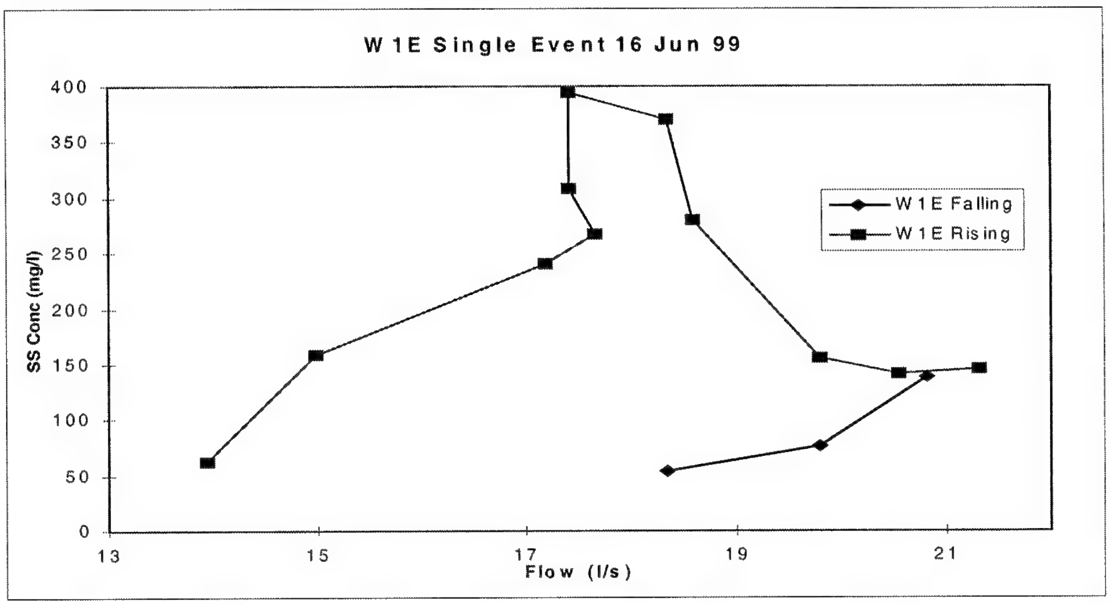



**Figure 3-24. W1E Typical Clock Wise Hysteresis**

The response of W1 combines the varied responses of W1N and W1E. W1 tends to have a high early spike with the arrival of the first flush from W1N and a lower peak with the later arrival of sediment from W1E. The combination of sediment deliveries from the two tributaryes generally results in the sediment concentration of W1 peaking early but maintaining a high concentration and then having a smaller second peak on the rising limb. Generally, short duration storms with the first flush have a clockwise

hysteresis and a very slight second peak. During longer events, the delayed response from W1E results in a smaller but notable second peak. If this peak arrives before peak discharge, it exaggerates the clockwise hysteresis (Figure 3-25). If it arrives after peak discharge it causes a combination of both a clockwise and a counter-clockwise hysteresis (Figure 3-26).

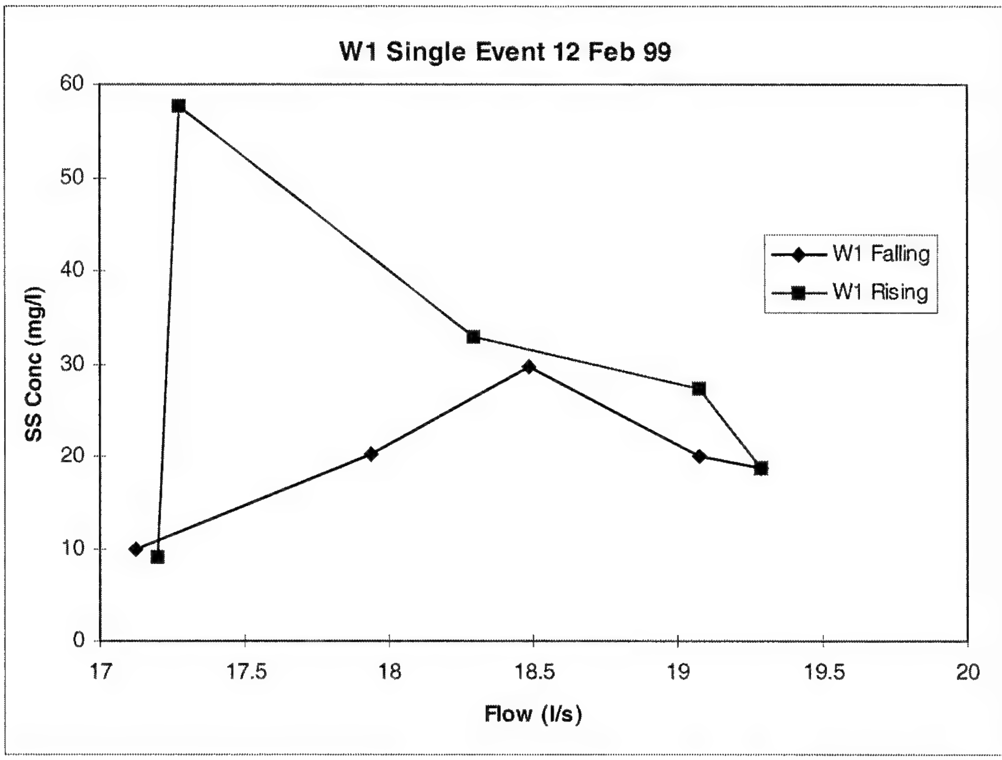



**Figure 3-25. W1 Clockwise Hysteresis with the Quick W1N First Flush and the W1E Sediment Arriving Before Peak Diacharge**

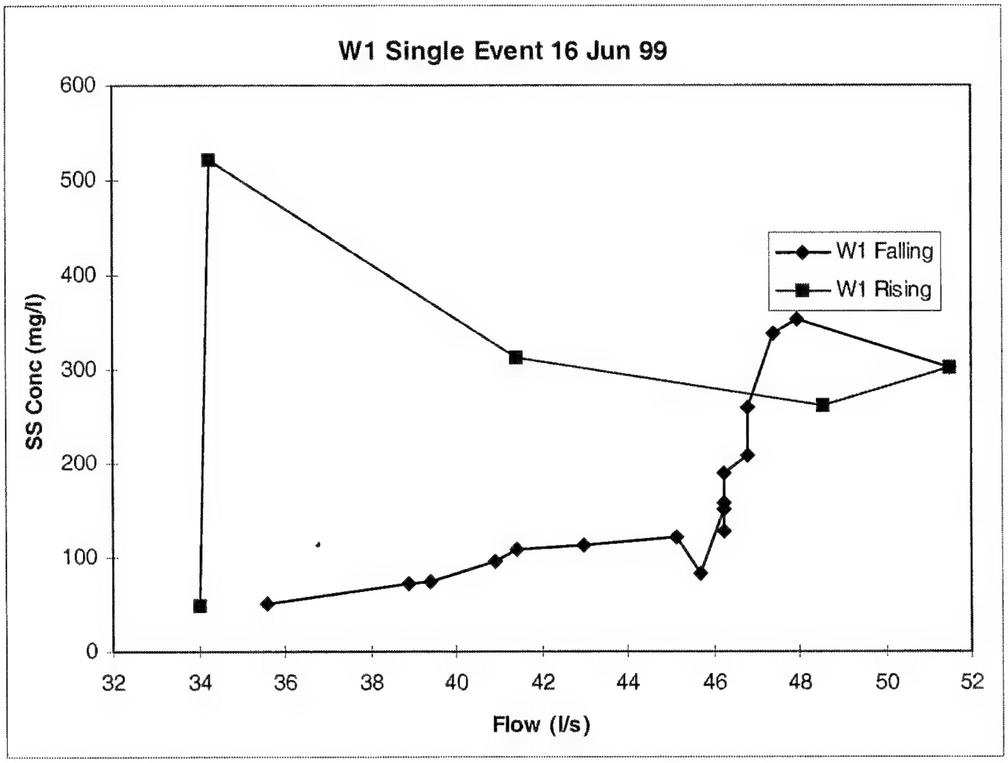



**Figure 3-26. W1 Complex Hysteresis with Early W1N first Flush and Late Arrival of W1E sediment Pulse after Peak Discharge**

## Unit Flux and Unit Flow of W1E and W1N

W1N and W1E rating curves of unit flux against unit flow were created to evaluate differences between contributions from the two tributaries (Figure 3-27). By integrating the sediment concentration data over storm durations and dividing by the drainage area, much of the storm variability in sediment loads is removed. For example, explained variance is increased from 0.31 for the raw W1E concentration data to 0.90 for the storm fluxes. A higher degree of unexplained variability ($R^2 = 0.47$) in W1N unit sediment flux is still present. ANCOVA shows no significant difference between W1E and W1N at the 0.05 alpha level with ($F= 0.03$ and P ($>F = 0.8574$). Therefore, these

results could not reject $H_{3o}$ and conclude no significant difference between the W1E and W1N unit sediment flux.

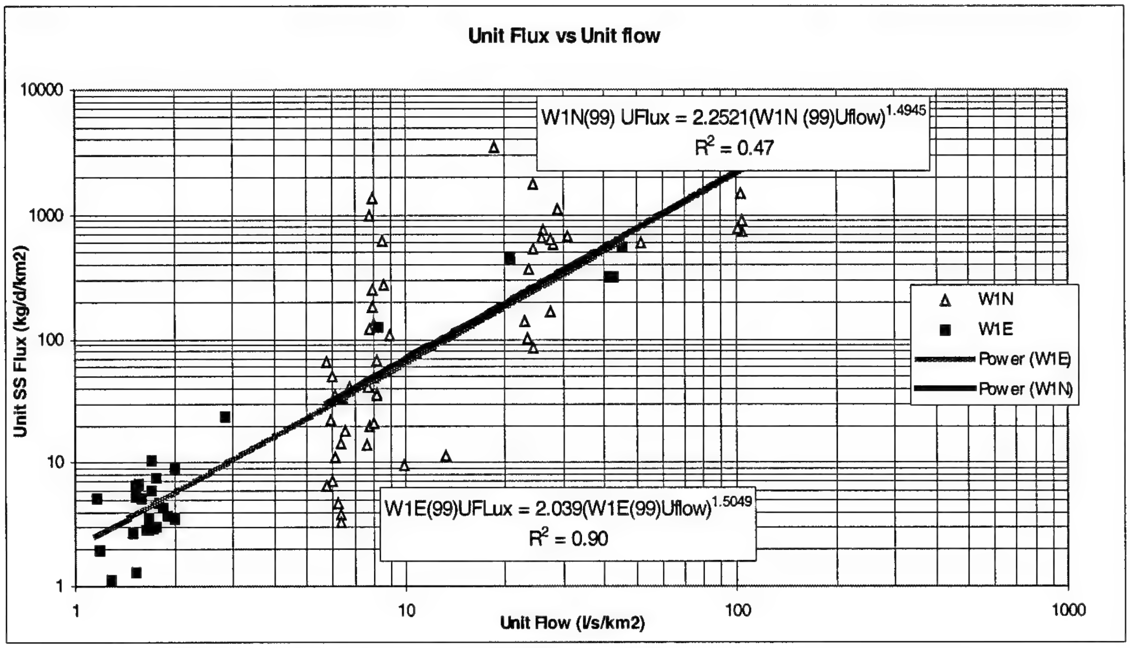



**Figure 3-27. W1E and W1N (1999) Unit Flux and Unit Flow**

## Land-Use Changes

In early December 1999, extensive land-use changes occurred. Active logging began with major portions of W1E basin being effected. The channel was greatly altered by the addition of tree stumps and logs. The dirt roads were graded and extensive vehicle traffic loosened the dirt surface. One storm, on 10 January 2000, was sampled to evaluate any significant changes after the change in land use. Using all data for W1E, reasonable rating curves were generated with pre-harvest and post-harvest sediment data stratification (Figure 3-28). Unit sediment flux was different after harvesting and ANCOVA results show a significant difference in the slope of the W1E post harversting unit flux unit flow rating curve. W1N had a uncharacteristically high runoff response

from this storm. Field observations indicated that this atypical response from W1N was due to overbank discharge from W1E which crossed over the floodplain about 100 m upstream of the gage sites and flowed into the W1N tributary. This was the first time this overflow from W1E to W1N had been observed and the high stage (465 mm at G1) was approximately double any previous observed stage heights (maximum at 215 mm at G1). Thus comingling of the W1E water with W1N is not likely to have effected the other samples. This shared discharge and the limitation of only one post-harvest event make it difficult to precisely specify the relative contributions of runoff for the two tributaries and are viewed as preliminary. The evaluation of response from change in land-use for W1N was not done.

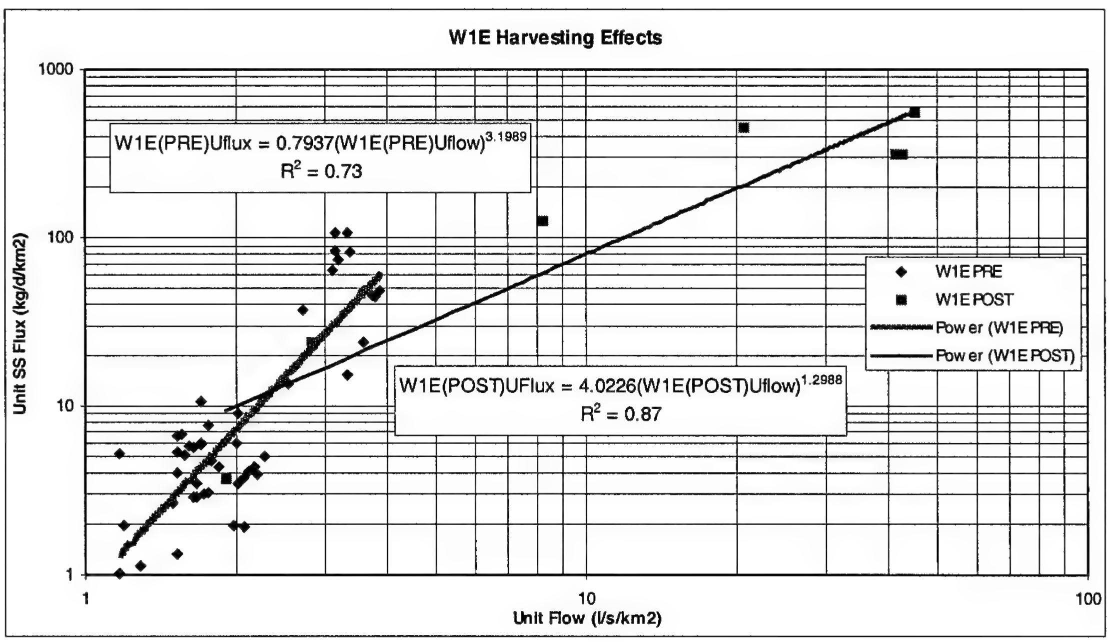



**Figure 3-28. W1E Sediment Flux Curves before and after Timber Harvesting**

## SUMMARY OF ANALYSIS

High erosion rates and effective transport of the sediment on the dirt roads show that the dirt roads are sources of accelerated erosion and sediment transport. Much of the eroded sediment is stored at the base of the roads studied but this may not always be the case. High variability in lumped erosion models make it difficult to accurately predict soil loss in such a diverse environment especially with the important role of the dirt roads as effective channels for runoff and sediment transport. Alterations to the soil horizon through many years of road grading have drastically increased the difficulty of accurately parameterizing a model.

Precipitation totals for this study period were approximately 40 cm below regional averages with no substantial contribution from hurricane events. Stage-discharge relationship at W1E were established through field measurements of ten storm events and functionalized with second-order polynomials. At the W1 main gage the exsiting rating-curve was used (Dean et al. 1998; 2000). Continuous stage recorders were established on both the east tributary (gage 7) and the main stream channel (gage1). However, equipment failures in May and December limited the stage data recorded. The mV data from the recorders were functionalized to correspond to field observed staff gage heights at their respective gages and subsequently converted to discharge by applying the stage-discharge function (Figures 2-3 and 2-4).

Interrill erosion was examined through 2 foot by 2 foot wooden small box plots by testing unit sediment mass differences between dirt road plots and controls placed in forested areas. The dirt road unit sediment mass mean was tested and found to be significantly greater than forested unit sediment mass at the 0.05 alpha level (t-Stat =

2.3152 and P ($T \leq t$) = 0.0342) (Figure 3-9). Field observations indicated that raindrop splash erosion was a more dominant process than sheet erosion at the small box-plot scale.

Rill erosion was measured through field surveys of cross-sections on a hillslope (R3, Figure 3-7) and roadside gully (R2, Figure 2-8). The R3 cross-section five-month soil loss was estimated to have been 15.7 kg/m$^2$ or 70 tons/ac (Table 3-1). The R2 cross-section five-month soil loss was estimated to have been 1.42 kg/m$^2$. Both erosion estimates indicate that rill erosion is dominant in areas of channelized flow and resulted in high losses of road sediment. Field observations of large sediment plumes below these sites indicate effective transport of road sediment from both the road surface and along the roadside gullies. Thus, roads produced significantly higher sediment and $H1_o$ was rejected.

Sediment deposition was noted at several locations within the study area and primarily at locations where road runoff entered the forest woodline. Plastic mats were used as sediment traps to measure deposition in the forest transition zone or buffer zone between sediment sources and stream channels. The unit weight (kg/m$^2$) of sediment deposition was measured across five transects with a gradient less than 2 percent (Figure 2-9). The unit weights along the mat transects indicate that a large portion of the sediment was trapped in the first 10 m of the buffer zone with a decline to zero at around 30 m and a slight increase at the 40 m buffer width (Figure 3-10). The mean unit mass deposited at the first 10 m buffer width was significantly greater than the combined mean deposition weights at the other three sites at the 0.05 alpha level (t-Stat = 2.27 and P (T<=t) is 0.04). A statistical regression of the unit mass against transect distance explains

70% of the variance (Figure 3-11). Deposition mat textural analysis reinforced the unit mass findings showing that the greatest percentage of sand was deposited in the first 10 m of the buffer. This indicates that the larger sand particles are settling out quickly while the fine sediment is being transported further along the transect. There is also an increase in organic matter along the transect as the runoff mobilizes the litter layer. Sand textures measured by sonic-sieving show very little material coarser than sand (> 2mm) was transported and that the coarse sands (> 0.5mm) generally decrease with an increase in buffer width. There is also a sharp increase in the fine and very fine sand particles (<0.25mm and >0.63mm) and in organics (based on LOI) with the maximum occuring with buffer widths of 30 m. These patterns indicate that deposition is occurring in the lower velocity flow environments after the larger particles had settled. These results for moderate sized storm event have significant deposition of sediment with distance along a buffer zone. Thus, $H_{20}$ is rejected.

The relationship between sediment concentration and discharge at W1 is complex due to the varied responses from the two tributaries. The first-flush phenomenon apparent in W1N is a result of road runoff reaching the stream through an area of inadequate buffer zone. The delayed response fromW1E also results in an out-of-phase relationship between peaks of discharge and suspended sediment concentrations. During a high discharge event on 10 Jan 2000, the two tributaries had similar sediment color and timing of peak stages. Field observations however, found that this concurrent timing was due to shallow overbank flows passing from W1E to W1N approximately 100 m to 300 m upstream from the confluence. The storm sediment flux totals from five moderate events indicated no significant difference between the total sediment flux of W1E and

W1N when averaged. Comparison of the overall unit sediment flux between the W1E and W1N indicated no significant difference between the two tributaries. Thus, these results could not reject the third null hypothesis, $H_{30}$, that there is no significant difference between unit sediment fluxes at W1N and W1E.

# CHAPTER IV

# DISCUSSION AND SYNTHESIS

Results from this study show that soil erosion, sediment transport, and sediment deposition are significantly affected by the presence of dirt roads. The high proportion of dirt road surface area in the W1 watershed generated high rates of erosion, and the narrow buffer zone widths allows these sediments to be conveyed to the efficient ditch system.

## *IMPLICATIONS AND FUTURE RESEARCH*

The presence and use of the dirt roads in the W1 watershed, combined with the exposed sandy soil and intense rainfall potential of the Sandhills environment of South Carolina, and inadequate buffer zones combine to accelerate soil erosion and sediment transport and are a concern for NPS sediment generation. Sediment generation was observed along the road on the northern side of W1N and the tributary coming from the BRM-19 rifle range along the east channel. Soil erosion management should begin with an investigation of these major sediment sources, the impact of dirt roads, and the ability of buffer zones to control transport of sediment in this environment.

### Erosion and Transport

Erosion from dirt roads has been shown to be larger than the forested areas; i.e., $H_{1o}$ is rejected. Although locally efficient road maintenance and soil erosion reduction efforts have been initiated on Ft Jackson, a relatively small number of highly erosion-prone areas are contributing heavily to sediment yields. For example, field observations

of overland flow from the BRM-19 rifle range and blocked drainage channels below it indicate sustained gully formation via scouring directly below this source. A steel sediment retention dam has been constructed below the rifle range, but field observations and suspended sediment samples at the dam outlet indicate substantial sediment loads are passing through this structure. Recent gully activity below the BRM-19 range and scouring by overland flow above the dam are rapidly producing sediment, which will reduce the reservoir capacity and the useful life span of the dam. Reducing overland flow from the BRM-19 rifle range by cleaning drains and channels and stabilizing gullies should have significant impacts on sediment production and sediment yield from this site. Field observations along the main east tributary channel revealed that the majority of sediment reaching the channel came from the rifle range. Other sources of sediment reaching the east channel were roadside ditches especially those draining Old Harstville Guard Road and Firebreak 11 where it joins the BRM19 rifle range tributary.

Three erosion-prone areas were observed along the W1N channel. Two were areas of road runoff into the wetland at the upstream end of the ditched channel. A steep road rill that was shown by repeat surveys to be the source of 15.7 $kg/m^2$ of sediment during a six-month period deposited this sediment at the base of the hillslope were it was susceptible to further transport by subsequent large events. Some of the eroded sediment was carried off-site to the ephemeral stream network where it could be deposited or remobilized. The third area was about 50 m upstream of the confluence with the W1E that drained about 100 m of dirt road surface.

**Deposition**

During the study, flow from W1E exceeded bank-full conditions and crossed the floodplain and into W1N, indicating that in high runoff events the wetland loses retention efficiency and allows higher sediment yields to leave the W1E basin circumventing the gage site. The null hypothesis two, that there would be no effect of buffers was rejected. Thus, buffer zones were effective in reducing the amount of sediment reaching the stream channel network during the moderate magnitude flows monitored by this study. Sediment deposition along transects entering a wetland indicate that buffer zone widths of 10 m are effective in trapping coarse sand and reducing the transport of fines. These results were only from the moderate storm events sampled and effective widths of buffer zones may expand substantially with larger storms. Areas of inadequate buffer zone width below erosion-prone areas may result in conveyance of sediment directly to streams. In this ditched system, main channels are highly efficient at sediment transport so these inputs are quickly delivered to the system of ponds downstream of the W1 outlet. Improving the buffer zone width by only a few meters at the narrow spots along the dirt road that parallels W1N should substantially reduce sediment loads in road runoff that empties directly into the channel. In forest transition zones below dirt roads large active sediment plumes were observed. These sediment deposits cause valley aggradation and may ultimately steepen slopes and reduce sediment storage capacity.

**Sediment Yield**

High suspended sediment concentrations from storm events with high intensities and from large runoff events indicates that sediment is being transported from this watershed. Variability in sources of suspended sediment including W1N direct road

runoff, (the “first-flush” phenomenon), and W1E overbank flows entering W1N-make long-term sediment yield calculations difficult and somewhat speculative with only a small data set. The first-flush phenomenon was most apparent in the north tributary during summer (convectional storms) within fifteen minutes of precipitation and caused high variability in sediment rating curves. Removal of the first flush decreased the variability in sediment discharge rating curves. Seasonal stratification produced rating curves with the least amounts of unexplained variance. Winter storm rating curves had nearly the same variability with or without first flush inclusion. Removal of the first flush substantially decreased summer storm sediment discharge rating curve variability.

Sediment loads in W1E were not found to be significantly larger than sediment loads in W1N by analysis of five storm sediment flux and runoff discharge values. Additionally, no significant difference was found between unit flux-unit flow rating curves for these tributaries through analysis of covariance. Since, null hypothesis three could not be rejected in both cases the unit sediment fluxes (scaled per unit drainage area) from W1N and W1E were not different for the evens of this study. This was surprising given the close proximity of W1N ditch system and the greater length of wetland that W1E passes through.

A preliminary geographic information system (GIS) buffer zone analysis was conducted to calculate the dirt road densities in proximity to the W1N and W1E stream channels. It was anticipated that the W1N sub-basin would have a higher road density than the W1E sub-basin. This was not the case with buffer widths less than fifty meters. W1E had a substantially higher density in the 10 m, 20 m, and 30 m buffer widths than W1N. At buffer widths greater than fifty meters, W1N had a higher density. This was

due to the general orientation of the dirt roads and firebreaks in relation to the stream channels. For W1N, the firebreaks were mainly perpendicular to the channels with some dirt roads paralleling the channels. W1E had the opposite orientation. A large contribution to W1E dirt road density was the inclusion of streams along Old Hartsville Guard Road and the BRM-19 rifle range tributary. Additionally, a few areas of Old Hartsville Guard Road (approximately 100m by 100 m) of timber had been cleared for the timber harvesting machinery and large trucks. Field observations revealed that these dirt roads and firebreaks in close proximity to the stream channels efficiently conveyed both water and sediment to the ditched channels.

Future research is needed to improve the suspended sediment data, establish more accurate rating curves, and combine this information with flow-duration curves to establish long-term sediment yields such as annual loadings. Comparisons of discharges at W1, W1E, and W1N indicates that continuity exists between the gages, so presumably, the delivery of sediment to the W1E ditch channel by the BRM-19 tributary explains this observation. Maintaining continuous discharge loggers at the main channel and the east tributary will allow calculations of water and sediment on W1N. These data will allow the development of future discharge frequency curves, evaluation of sediment delivery ratios, and evaluation of the effects of land-use changes. Improved soil erosion models such as the WEPP model will enhance the predictions of erosion, sediment, and identification of processes in such spatially diverse environments (Elliot et al. 1994).

# CHAPTER V

# CONCLUSION

The goal of this research was to observe the physical processes involved in hillslope soil erosion and movement in a rural Sandhills environment. The bifurcation of a watershed into two distinct sub-basins provided the opportunity to observe their different responses in a paired-watershed experiment. Similarities of soils, vegetation, and climate between the watersheds allowed study of the effects of buffer zones and dirt roads on sediment budgets for the two watersheds. Three hypotheses were tested concerning different responses in erosion, deposition, and transport of sediment. In short, the first two null hypotheses were rejected but the third null hypothesis could not be rejected.

The first hypothesis, that entrainment and transport of sediment along the dirt roads is greater than on hillslopes, was tested by collecting sediment from raindrop splash erosion in small box plots and cross-sectional measurements along a dirt road hillslope profile. Unit sediment masses from boxes on the dirt road (49 $kg/m^2$) were found to be significantly larger than unit sediment masses from a forested area (1 $kg/m^2$). Soil loss rates were also determined along a dirt road from cross-section repeat surveys and were found to exceed the county soil-loss tolerance factor (T). These surveys indicate effective sediment transport along the roads although much of the sediment appears to have been deposited locally.

The second hypothesis, that a substantial portion of the total sediment load is stored along the wetland buffer zone, was tested by placing plastic turf mats as sediment deposition traps along transects across buffer zones. Observations of sediment deposition masses and particle-size distributions showed that most deposition occurred within a short distance (10 m to 20 m) into the wetland. Sediment deposition along wetland margins was significantly greater at 10 m into the buffer zone than the combined sedimentation at the buffer zone widths from 20 m to 40 m. Regression analysis indicates a sharp reduction occurred in the transport of sediment through a buffer zone that has a width of at least ten meters (Figure 3-11). These results were observed in moderate size storm events, so, sediment transport further into or completely across buffer zones may occur with larger storm events. Nevertheless, the efficient detention of sediment by buffers during frequent moderate magnitude events indicates their effectiveness as a NPS management tool.

The third hypothesis, that the north tributary (W1N) will have a higher sediment yield per unit area than the east tributary (W1E) was tested using sediment concentration data from water samples collected during storms. There was no significant difference (alpha = 0.05) in total storm flux between W1E and W1N for the five selected events. Additionally, ANCOVA shows no significant difference (alpha = 0.05) in unit flux rating curves between W1E and W1N. The lack of difference in sediment loadings between the two tributaries may be a reflection of different responses. During smaller storm events, W1N produced higher portions of unit sediment flux than did W1E. During larger events, W1E produced a higher unit sediment flux averaged over the five storms. Regression analysis of sediment rating curves also indicates variable response in the

discharge and suspended sediment concentrations between W1N and W1E. Greater sediment loads were expected in the W1N sub-basin due to road proximity and the large extent of wetland the W1E channel passed through. This study revealed, however, that there is a very high road density in the lower W1E sub-basin and that high sediment loads delivered by the BRM-19 rifle range tributary are efficiently transported by the W1E ditched channel.

Recent timber harvesting across the watershed allowed comparisons of suspended sediment data for preharvest and post-harvest periods to evaluate change in sediment flux due to land-use changes. Changes in land-use were examined by ANCOVA to evaluate any response to changes in the east tributary. With sediment flux data from only one post-harvest storm event there was significant difference (alpha = 0.05) when compared with the remaining sediment flux data. More data are needed to determine whether this difference is attributed to seasonality, land-use change, or event magnitude.

In addition to the hypothesis tests, field observations and laboratory measurements revealed several erosion and sediment processes. For example, regression analysis of suspended sediment concentration, discharge, unit flux, and unit flow determined stage-discharge functions and sediment rating curves (Meade, Yuzyk, and Day, 1990, James 1998). Data were stratified by season, type of precipitation event, rising versus falling limbs of hydrographs, and by year to identify the dominant processes driving sediment deliveries. Sediment loads and discharges varied by tributary and against previous study data. The existence of a first flush phenomenon, over-bank flooding of the east tributary into the north tributary, and the delayed arrival of the east tributary peak discharge and peak sediment loads make highly variable rating curves. Stratification of sediment

concentration by season and by time (within the duration of storms) allowed much improved sediment ratings curves to be achieved. In particular, winter data alone resulted in higher explained variance ($R^2$ of 0.54). Summer suspended sediment data ($R^2 = 0.38$) had much unexplained variance and was further stratified to isolate the first flush sediment arrival, which were not well related to discharge. This increased explained variance to ($R^2 = 0.54$).

This study indicates that dirt roads and firebreaks are areas of accelerated erosion and act as part of an efficient channel network for the entrainment and transport of sediment particles. The importance of buffers between these roads and stream channels was evident in the significant reduction of sediment deposition over short distances across buffers. Given the pronounced density of dirt roads and firebreaks in this sandy environment, in areas with inadequate buffer zone widths, unchecked road runoff acts as an important source of non-point source pollution to ditches, which efficiently carry it down stream.

**Future Research**

Continued collection of discharge and suspended sediment concentration data from the east tributary and the main channel would be most productive in expanding the watershed database. Few large runoff events were sampled by this thesis research and this would greatly extend the range of data in the W1N and W1E tributaries. This expansion of the data range would improve stage-discharge functions and sediment-rating curves. Furthermore, the development of flow-duration curves, from the continuous stage data record would allow evaluation of the long-term sediment yield. Expansion of preliminary WEPP model applications along with other recent erosional models would

allow insight into the production and movement of sediment throughout the watershed. Historical analysis of land use and sedimentation of erosion-prone areas can also provide an understanding of watershed erosion and runoff response changes.

# Appendix A

## Unit Sediment Masses from Small Box Plots

## List of Tables

| Sample Label | * Mass (g/box) |
|---|---|
| F1A | 11.8 |
| F1B | 2.73 |
| F2A | 3.72 |
| F2D | 0.765 |
| F3C | 2.03 |
| **R2B** | 38.1 |
| **R2C** | 84 |
| **R3A** | 370 |
| **R3B** | 29.4 |
| **R4A** | 498 |
| **R4B** | 119 |

**Bold** denotes dirt road sampling
* For a 5 month period (16 Jun 99 to 19 Nov 99)

Table A-1 Unit Sediment Mass Data

## Appendix B

## Road Hillslope and Gully Cross-section Surveys

## List of Tables

|  | 4 Jun 99 | 7 Jul 99 | 10-Sep-99 | 19-Nov-99 | 4-Jun-99 | 7-Jul-99 | 10-Sep-99 | 19-Nov-99 |
|---|---|---|---|---|---|---|---|---|
| **Cross Section: 15 m** |  |  |  |  |  |  |  |  |
| Instrument Height (m) |  |  |  |  | 1.65 | 1.642 | 1.63 | 1.56 |
| Interval Distance (m) | Height (m) **4 Jun 99** | Height (m) **7 Jul 99** | Height (m) **10-Sep-99** | Height (m) **19-Nov-99** | Field Height (m) **4-Jun-99** | Field Height (m) **7-Jul-99** | Field Height (m) **10-Sep-99** | Field Height (m) **19-Nov-99** |
| 8.5 | 0.379 | 0.383 | 0.391 | 0.406 | 1.473 | 1.551 | 1.563 | 1.516 |
| 7.7 | 0.556 | 0.543 | 0.543 | 0.554 | 1.65 | 1.711 | 1.715 | 1.664 |
| 7.3 | 0.861 | 0.91 | 0.894 | 0.885 | 1.955 | 2.078 | 2.066 | 1.995 |
| 6.8 | 1.181 | 1.232 | 1.193 | 1.19 | 2.275 | 2.4 | 2.365 | 2.3 |
| 6.45 | 1.221 | 1.227 | 1.243 | 1.235 | 2.315 | 2.395 | 2.415 | 2.345 |
| 6.05 | 1.223 | 1.252 | 1.258 | 1.273 | 2.317 | 2.42 | 2.43 | 2.383 |
| 5.68 | 1.225 | 1.222 | 1.24 | 1.273 | 2.319 | 2.39 | 2.42 | 2.383 |
| 5.6 | 1.227 | 1.22 | 1.238 | 1.273 | 2.321 | 2.387 | 2.41 | 2.383 |
| 5.3 | 1.171 | 1.216 | 1.228 | 1.253 | 2.265 | 2.384 | 2.4 | 2.363 |
| 5.2 | 1.157 | 1.213 | 1.22 | 1.213 | 2.245 | 2.381 | 2.38 | 2.323 |
| 5 | 1.137 | 1.142 | 1.19 | 1.175 | 2.225 | 2.31 | 2.36 | 2.285 |
| 4.95 | 1.111 | 1.129 | 1.168 | 1.138 | 2.205 | 2.297 | 2.34 | 2.248 |
| 4.55 | 1.063 | 1.063 | 1.063 | 1.061 | 2.157 | 2.231 | 2.28 | 2.171 |
| 4.15 | 1.046 | 1.037 | 1.043 | 1.042 | 2.14 | 2.205 | 2.215 | 2.152 |
| 3.72 | 0.996 | 0.982 | 1 | 0.974 | 2.09 | 2.15 | 2.172 | 2.084 |
| 3.39 | 0.838 | 0.812 | 0.873 | 0.79 | 1.932 | 1.98 | 2.045 | 1.9 |
| 2.95 | 0.601 | 0.602 | 0.603 | 0.585 | 1.695 | 1.77 | 1.775 | 1.695 |
| 2.6 | 0.476 | 0.472 | 0.473 | 0.462 | 1.57 | 1.64 | 1.645 | 1.572 |
| 2.09 | 0.286 | 0.302 | 0.373 | 0.308 | 1.38 | 1.47 | 1.545 | 1.418 |
| 1.54 | 0 | 0 | 0 | 0 | 1.094 | 1.168 | 1.172 | 1.11 |

Table B-1. (15m)

| | 4-Jun-99 | 7 Jul 99 | 10-Sep-99 | 19-Nov-99 | 4 Jun 99 | 7 Jul 99 | 10-Sep-99 | 19-Nov-99 |
|---|---|---|---|---|---|---|---|---|
| **Cross Section: 40 m** | | | | | | | | |
| Instrument Height (m) | | | | | 1.65 | 1.642 | 1.63 | 1.56 |
| Interval Distance (m) | Height (m) **4-Jun-99** | Height (m) **7 Jul 99** | Height (m) **10-Sep-99** | Height (m) **19-Nov-99** | Field Height (m) **4 Jun 99** | Field Height (m) **7 Jul 99** | Field Height (m) **10-Sep-99** | Field Height (m) **19-Nov-99** |
| 7.55 | 0.265 | 0.21 | 0.279 | 0.265 | 2.895 | 2.945 | 3.01 | 2.97 |
| 7.2 | 0.64 | 0.615 | 0.577 | 0.621 | 3.27 | 3.35 | 3.308 | 3.326 |
| 6.95 | 1.24 | 1.212 | 1.169 | 1.245 | 3.87 | 3.947 | 3.9 | 3.95 |
| 6.7 | 1.2 | 1.211 | 1.249 | 1.229 | 3.83 | 3.946 | 3.98 | 3.934 |
| 6.24 | 1.23 | 1.24 | 1.369 | 1.276 | 3.86 | 3.975 | 4.1 | 3.981 |
| 5.9 | 1.165 | 1.15 | 1.214 | 1.182 | 3.795 | 3.885 | 3.945 | 3.887 |
| 5.5 | 1.125 | 1.11 | 1.169 | 1.14 | 3.755 | 3.845 | 3.9 | 3.845 |
| 5 | 1.11 | 1.08 | 1.134 | 1.095 | 3.74 | 3.815 | 3.865 | 3.8 |
| 4.58 | 1.095 | 1.07 | 1.123 | 1.085 | 3.725 | 3.805 | 3.854 | 3.79 |
| 4.1 | 1.085 | 1.065 | 1.116 | 1.082 | 3.715 | 3.8 | 3.847 | 3.787 |
| 3.45 | 1.07 | 1.051 | 1.114 | 1.053 | 3.7 | 3.786 | 3.845 | 3.758 |
| 3.1 | 0.925 | 0.932 | 0.929 | 0.899 | 3.555 | 3.667 | 3.66 | 3.604 |
| 2.8 | 0.783 | 0.745 | 0.784 | 0.742 | 3.413 | 3.48 | 3.515 | 3.447 |
| 2.6 | 0.245 | 0.415 | 0.436 | 0.415 | 2.875 | 3.15 | 3.167 | 3.12 |
| 2 | 0 | 0 | 0 | 0 | 2.63 | 2.735 | 2.731 | 2.705 |

Table B-2. (40m)

| | **4-Jun-99** | **7-Jul-99** | **10 Sep 99** | **19 Nov 99** | **4 Jun 99** | **7-Jul-99** | **10 Sep 99** | **19 Nov 99** |
|---|---|---|---|---|---|---|---|---|
| **Cross Section: 75 m** | | | | | | | | |
| Instrument Height (m) | | | | | 1.65 | 1.64 | 1.66 | 1.436 |
| Interval Distance (m) | Height (m) **4-Jun-99** | Height (m) **7-Jul-99** | Height (m) **10 Sep 99** | Height (m) **19 Nov 99** | Field Height (m) **4 Jun 99** | Field Height (m) **7-Jul-99** | Field Height (m) **10 Sep 99** | Field Height (m) **19 Nov 99** |
| 6.55 | 0.02 | 0.037 | 0.048 | 0.04 | 5.66 | 1.987 | 2.01 | 1.835 |
| 6.2 | 0.155 | 0.173 | 0.183 | 0.163 | 5.795 | 2.123 | 2.145 | 1.958 |
| 5.9 | 0.435 | 0.455 | 0.45 | 0.45 | 6.075 | 2.405 | 2.412 | 2.245 |
| 5.35 | 0.46 | 0.442 | 0.451 | 0.477 | 6.1 | 2.392 | 2.413 | 2.272 |
| 4.9 | 0.45 | 0.445 | 0.452 | 0.488 | 6.09 | 2.395 | 2.414 | 2.283 |
| 4.32 | 0.45 | 0.454 | 0.463 | 0.492 | 6.09 | 2.404 | 2.425 | 2.287 |
| 3.9 | 0.485 | 0.455 | 0.467 | 0.451 | 6.125 | 2.405 | 2.429 | 2.246 |
| 3.5 | 0.465 | 0.462 | 0.452 | 0.487 | 6.105 | 2.412 | 2.414 | 2.282 |
| 3 | 0.48 | 0.478 | 0.477 | 0.494 | 6.12 | 2.428 | 2.439 | 2.289 |
| 2.5 | 0.48 | 0.475 | 0.473 | 0.474 | 6.12 | 2.425 | 2.435 | 2.269 |
| 2 | 0.465 | 0.475 | 0.484 | 0.466 | 6.105 | 2.425 | 2.446 | 2.261 |
| 1.6 | 0.26 | 0.363 | 0.382 | 0.365 | 5.9 | 2.313 | 2.344 | 2.16 |
| 1.25 | 0 | 0 | 0 | 0 | 5.64 | 1.95 | 1.962 | 1.795 |

Table B-3. (75m)

| **Position length (m)** | Height (m) Date:4 Jun 99 | Height (m) Date:7 Jul 99 | Height (m) Date:10 Sep 99 | Height (m) Date: 19 Nov 99 |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 15 | 0.55 | 0.613 | 0.753 | 0.803 |
| 35 | 1.76 | 1.842 | 1.853 | 1.9 |
| 60 | 3.61 | 3.708 | 3.87 | 3.805 |
| 75 | 4.44 | 4.508 | 4.728 | 4.705 |
| 98 | 5.25 | 5.338 | 5.658 | 5.555 |
| 90 | 5 | 5.188 | | 5.12 |

**Table B-4. R3 Length**

| **Position length (m)** | Slope Date:4 Jun 99 | Slope Date:7 Jul 99 | Slope Date:10 Sep 99 | Slope Date: 19 Nov 99 |
|---|---|---|---|---|
| **0** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **15** | 0.0367 | 0.0409 | 5.0263 | 5.3610 |
| **35** | 0.0503 | 0.0527 | 5.3017 | 5.4366 |
| **60** | 0.0603 | 0.0619 | 6.4635 | 6.3545 |
| **75** | 0.0593 | 0.0602 | 6.3166 | 6.2857 |
| **90** | 0.0556 | 0.0577 | | 5.6981 |
| **98** | 0.0536 | 0.0546 | 5.7831 | 5.6775 |

**Table B-5. R3 Slope**

# Appendix C

## Depositional Mat Sediment Particle Data

## List of Tables

| Buffer Width (m) | Unit weight (kg/m^2) 7-Jul-99 | Unit weight (kg/m^2) 10-Sep-99 | Unit weight (kg/m^2) 9-Oct-99 | Unit weight (kg/m^2) 19-Nov-99 | Unit weight (kg/m^2) 19-Nov-99 |
|---|---|---|---|---|---|
| 10 | 1.234 | 0.347 | 0.727 | 0.103 | 0.224 |
| 20 | 0.068 | 0.047 | 0.174 | 0.009 | 0.080 |
| 30 | 0.107 | 0.007 | 0.038 | 0.010 | 0.080 |
| 40 | 0.099 | 0.132 | 0.046 | 0.019 | 0.009 |

**Table C-1. Depositional Mat Data**

| ID # | Total dry Weight (g) | Weight after LOI (g) | Sample Weight (g) | Wet-SV Weight (g) | Sonic Sieving Weights 2000 (g) | 1000 (g) | 500 (g) | 250 (g) | 125 (g) | 63 (g) | Total (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-7A | 20.596 | 17.575 | 17.575 | 6.630 | 0.027 | 0.563 | 1.215 | 1.513 | 1.243 | 1.682 | 6.243 |
| 7-7B | 19.543 | 18.191 | 18.191 | 9.350 | 0.000 | 0.240 | 0.710 | 0.598 | 1.509 | 5.710 | 8.767 |
| 7-7C | 17.594 | 15.365 | 15.365 | 6.460 | 0.074 | 0.624 | 1.562 | 1.484 | 1.069 | 0.450 | 5.263 |
| 7-7D | 29.395 | 27.063 | 27.063 | 11.563 | 0.107 | 1.490 | 2.938 | 2.313 | 1.368 | 2.110 | 10.326 |
| 10-9A | 24.074 | 17.390 | 17.390 | 14.130 | 0.080 | 1.420 | 3.180 | 2.970 | 2.990 | 2.700 | 13.340 |
| 10-9B | 2.237 | 0.740 | 0.740 | 0.637 | 0.016 | 0.047 | 0.115 | 0.140 | 0.128 | 0.089 | 0.535 |
| 10-9C | 14.270 | 10.660 | 10.660 | 8.660 | 0.003 | 0.272 | 3.300 | 3.570 | 1.080 | 0.340 | 8.565 |
| 10-9D | 16.460 | 16.170 | 16.170 | 15.650 | 0.081 | 3.630 | 6.960 | 3.570 | 1.120 | 0.174 | 15.535 |
| 10-19A | 2.750 | 0.420 | 0.420 | 0.369 | 0.000 | 0.063 | 0.114 | 0.114 | 0.063 | 0.015 | 0.369 |
| 10-19B | 1.411 | 0.532 | 0.532 | 0.367 | 0.018 | 0.041 | 0.035 | 0.080 | 0.110 | 0.080 | 0.364 |
| 10-19C | 1.382 | 0.687 | 0.687 | 0.432 | 0.000 | 0.040 | 0.164 | 0.187 | 0.037 | 0.004 | 0.432 |
| 10-19D | 15.320 | 6.030 | 6.030 | 5.360 | 0.000 | 1.036 | 2.745 | 1.377 | 0.178 | 0.013 | 5.349 |
| 11-19A | 1.345 | 0.344 | 0.344 | 0.28 | 0 | 0.043 | 0.01 | 0.12 | 0.073 | 0.031 | 0.277 |
| 11-19B | 13.56 | 11.8 | 11.8 | 9.78 | 0.0489 | 1.061 | 2.761 | 3.306 | 1.943 | 0.0518 | 9.1717 |
| 11-19C | 12.98 | 11.8 | 11.8 | 10.94 | 0.083 | 1.62 | 4.518 | 3.335 | 1.139 | 0.214 | 10.909 |
| 11-19D | 30.03 | 25.73 | 25.73 | 21.53 | 0.0184 | 1.374 | 6.857 | 8.881 | 3.182 | 0.767 | 21.0794 |

**Table C-2 Depositional mat Lab Data**

# Appendix D

## Suspended Sediment Concentration and Discharge Data

### List of Tables

## List of Figures

Suspended Sediment analysis
W1, Fort Jackson, SC — Date of event: 12-Feb-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 1 (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) W1 12 Feb 99 |
|---|---|---|---|---|---|---|---|---|
| 51 | W1-1 | 103 | 156 | 112 | 57.69 | 125 | 17.27 | 86.10 |
| 52 | W1-4 | 102 | 152 | 107 | 32.89 | 131 | 18.30 | 52.00 |
| 53 | W1-7 | 104 | 146 | 108 | 27.40 | 135 | 19.08 | 45.16 |
| 54 | W1-10 | 103 | 160 | 106 | 18.75 | 136 | 19.28 | 31.24 |
| 355 | W1-13 | 103 | 100 | 105 | 20.00 | 135 | 19.08 | 32.97 |
| 56 | W1-16 | 103 | 101 | 106 | 29.70 | 132 | 18.48 | 47.44 |
| 57 | W1-19 | 103 | 99 | 105 | 20.20 | 129 | 17.94 | 31.31 |
| 58 | W1-22 | 102 | 101 | 103 | 9.90 | 124 | 17.12 | 14.65 |
| 59 QA/QC | W1-22 | 103 | 101 | 104 | 9.90 | 124 | 17.12 | 14.65 |
| | | | | | | Stage 7 (mm) | | W1E 12 Feb 99 |
| 73 | W1E-3 | 103 | 175 | 109 | 34.29 | 310 | 11.05 | 32.73 |
| 74 | W1E-6 | 103 | 143 | 106 | 20.98 | 312 | 11.41 | 20.68 |
| 75 | W1E-9 | 102 | 217 | 107 | 23.04 | 315 | 11.97 | 23.82 |
| 76 | W1E-12 | 104 | 159 | 108 | 25.16 | 318 | 12.54 | 27.25 |
| 77 | W1E-15 | 104 | 146 | 107 | 20.55 | 316 | 12.16 | 21.58 |
| 78 | W1E-18 | 103 | 180 | 107 | 22.22 | 313 | 11.60 | 22.26 |
| 79 | W1E-21 | 103 | 186 | 105 | 10.75 | 312 | 11.41 | 10.60 |
| 80 | W1E-24 | 103 | 174 | 105 | 11.49 | 309 | 10.87 | 10.80 |
| | | | | | | Stage 6 (mm) | | W1N 12 Feb 99 |
| 81 | W1N-2 | 103 | 122 | 119 | 131.15 | 126 | 6.22 | 70.53 |
| 82 | W1N-5 | 103 | 116 | 106 | 25.86 | 128 | 6.88 | 15.38 |
| 83QA/QC | W1N-5 | 103 | 117 | 106 | 25.64 | 128 | 6.88 | 15.25 |
| 84 | W1N-8 | 103 | 124 | 107 | 32.26 | 126 | 7.11 | 19.82 |
| 85 | W1N-11 | 102 | 114 | 103 | 8.77 | 129 | 6.75 | 5.11 |
| 86 | W1N-14 | 104 | 143 | 105 | 6.99 | 125 | 6.92 | 4.18 |
| 87 | W1N-17 | 103 | 164 | 104 | 6.10 | 122 | 6.89 | 3.63 |
| 88 | W1N-20 | 103 | 144 | 105 | 13.89 | 121 | 6.52 | 7.83 |
| 89 | W1N-23 | 102 | 151 | 104 | 13.25 | 121 | 6.25 | 7.15 |

**Table D-1. 12 Feb 1999 Single Storm Data**

Suspended Sediment analysis
W1, Fort Jackson, SC    Date of event: 16-Jun-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 1 (mm) | Flow (L/s) | Suspended Sediiment Flux (kg/d) W1 16 Jun 99 |
|---|---|---|---|---|---|---|---|---|
| 15 | W1-1 | 103 | 92 | 151 | 521.74 | 182 | 34.25 | 1544.00 |
| 16 | W1-2 | 105 | 83 | 131 | 313.25 | 197 | 41.42 | 1121.05 |
| 17 | W1-3 | 104 | 69 | 122 | 260.87 | 210 | 48.54 | 1094.14 |
| 18 | W1-4 | 103 | 73 | 125 | 301.37 | 215 | 51.51 | 1341.20 |
| 19 | W1-5 | 105 | 65 | 128 | 353.85 | 209 | 47.97 | 1466.43 |
| 20 | W1-6 | 104 | 68 | 127 | 338.24 | 208 | 47.39 | 1384.99 |
| 21 | W1-7 | 103 | 73 | 122 | 260.27 | 207 | 46.82 | 1052.98 |
| 22 | W1-8 | 103 | 67 | 117 | 208.96 | 207 | 46.82 | 845.36 |
| 23 | W1-9 | 104 | 74 | 118 | 189.19 | 206 | 46.26 | 756.20 |
| 24 | W1-10 | 104 | 70 | 115 | 157.14 | 206 | 46.26 | 628.11 |
| 25 QA/QC | W1-10 | 104 | 70 | 115 | 157.14 | 206 | 46.26 | 628.11 |
| 26 | W1-11 | 104 | 71 | 113 | 126.76 | 206 | 46.26 | 506.67 |
| 27 | W1-12 | 103 | 73 | 114 | 150.68 | 206 | 46.26 | 602.29 |
| 28 | W1-13 | 103 | 73 | 109 | 82.19 | 205 | 45.70 | 324.56 |
| 29 | W1-14 | 103 | 99 | 115 | 121.21 | 204 | 45.15 | 472.85 |
| 30 | W1-15 | 103 | 89 | 113 | 112.36 | 200 | 42.99 | 417.33 |
| 31 | W1-16 | 102 | 92 | 112 | 108.70 | 197 | 41.42 | 388.99 |
| 32 | W1-17 | 103 | 95 | 112 | 94.74 | 196 | 40.91 | 334.84 |
| 33 | W1-18 | 104 | 94 | 111 | 74.47 | 193 | 39.40 | 253.49 |
| 34 | W1-19 | 103 | 83 | 109 | 72.29 | 192 | 38.91 | 243.00 |
| 35 | W1-20 | 103 | 98 | 108 | 51.02 | 185 | 35.60 | 156.91 |

**Table D-2. 16 Jun 1999 Single Storm Data**

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 7 (mm) | Flow (L/s) | Suspended Sediiment Flux (kg/d) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | W1E 16 Jun 99 |
| 36 | W1E-1 | 102 | 81 | 107 | 61.73 | 325 | 13.94 | 74.33 |
| 37 | W1E-2 | 103 | 76 | 115 | 157.89 | 330 | 14.98 | 204.33 |
| 38 | W1E-3 | 103 | 75 | 121 | 240.00 | 340 | 17.19 | 356.37 |
| 39 QA/QC | W1E-3 | 104 | 75 | 122 | 240.00 | 341 | 17.42 | 361.14 |
| 40 | W1E-4 | 103 | 71 | 122 | 267.61 | 342 | 17.65 | 408.03 |
| 41 | W1E-5 | 103 | 52 | 119 | 307.69 | 341 | 17.42 | 462.99 |
| 42 | W1E-6 | 103 | 76 | 133 | 394.74 | 341 | 17.42 | 593.97 |
| 43 | W1E-7 | 103 | 73 | 130 | 369.86 | 345 | 18.35 | 586.46 |
| 44 | W1E-8 | 103 | 68 | 122 | 279.41 | 346 | 18.59 | 448.79 |
| 45 | W1E-9 | 102 | 71 | 113 | 154.93 | 351 | 19.81 | 265.12 |
| 46 | W1E-10 | 103 | 71 | 113 | 140.85 | 354 | 20.56 | 250.14 |
| 47 | W1E-11 | 102 | 69 | 112 | 144.93 | 357 | 21.32 | 266.96 |
| 48 | W1E-12 | 102 | 87 | 114 | 137.93 | 355 | 20.81 | 247.98 |
| 49 | W1E-13 | 103 | 78 | 109 | 76.92 | 351 | 19.81 | 131.63 |
| 50 | W1E-14 | 103 | 75 | 107 | 53.33 | 345 | 18.35 | 84.57 |
| | | | | | | Stage 6 (mm) | | W1N 16 Jun 99 |
| 1 | W1N-1 | 104 | 62 | 238 | 2161.29 | 145 | 20.32 | 3793.60 |
| 2 | W1N-2 | 104 | 48 | 145 | 854.17 | 150 | 26.44 | 1951.45 |
| 3 | W1N-3 | 103 | 82 | 140 | 451.22 | 160 | 31.36 | 1222.50 |
| 4 | W1N-4 | 103 | 94 | 127 | 255.32 | 165 | 33.86 | 746.96 |
| 5 | W1N-5 | 103 | 90 | 125 | 244.44 | 170 | 30.55 | 645.22 |
| 6 | W1N-6 | 103 | 79 | 124 | 265.82 | 175 | 29.98 | 688.48 |
| 7 | W1N-7 | 103 | 63 | 124 | 333.33 | 178 | 28.47 | 820.02 |
| 8 | W1N-8 | 103 | 71 | 124 | 295.77 | 178 | 28.23 | 721.54 |
| 9 | W1N-9 | 104 | 81 | 125 | 259.26 | 162 | 26.46 | 592.61 |
| 10 | W1N-10 | 104 | 77 | 118 | 181.82 | 155 | 25.71 | 403.83 |
| 11 | W1N-11 | 103 | 99 | 110 | 70.71 | 150 | 24.94 | 152.38 |
| 12 | W1N-12 | 104 | 100 | 109 | 50.00 | 149 | 25.45 | 109.96 |
| 13QA/QC | W1N-12 | 104 | 100 | 109 | 50.00 | 149 | 25.45 | 109.96 |
| 14 | W1N-13 | 103 | 99 | 107 | 40.40 | 142 | 26.46 | 92.36 |

**Table D-2. 16 Jun 1999 Continued Single Storm Data**

Suspended Sediment analysis
W1, Fort Jackson, SC

Date of event: 25-Jun-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 1 (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) W1 25 Jun 99 |
|---|---|---|---|---|---|---|---|---|
| 69 | W1-1 | 103 | 136 | 108 | 36.76 | 95 | 14.87 | 47.22 |
| 70 | W1-2 | 103 | 140 | 110 | 50.00 | 108 | 15.36 | 66.34 |
| 71 | W1-3 | 103 | 130 | 108 | 38.46 | 112 | 15.68 | 52.10 |
| 72 | W1-4 | 103 | 160 | 111 | 50.00 | 115 | 15.97 | 69.00 |
| | | | | | | Stage 7 (mm) | | W1E 25 Jun 99 |
| 60 | W1E-1 | 103 | 100 | 106 | 30.00 | 294 | 8.40 | 21.77 |
| 61 | W1E-2 | 103 | 97 | 107 | 41.24 | 297 | 8.87 | 31.59 |
| 62 | W1E-3 | 104 | 100 | 108 | 40.00 | 298 | 9.03 | 31.19 |
| 63 | W1E-4 | 104 | 100 | 108 | 40.00 | 300 | 9.35 | 32.31 |
| | | | | | | Stage 6 (mm) | | W1N 25 Jun 99 |
| 64 | W1N-1 | 104 | 186 | 112 | 43.01 | 106 | 6.47 | 24.03 |
| 65 | W1N-2 | 103 | 133 | 116 | 97.74 | 109 | 6.49 | 54.81 |
| 66 | W1N-3 | 103 | 133 | 112 | 67.67 | 115 | 6.65 | 38.89 |
| 67 | W1N-4 | 103 | 144 | 106 | 20.83 | 114 | 6.62 | 11.92 |
| 68 QA/QC | W1N-4 | 103 | 144 | 107 | 27.78 | 114 | 6.62 | 15.90 |

**Table D-3. 25 Jun 1999Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 19-Jul-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Stage 7 (mm) | Suspended Sediment Concentration (mg/l) | Flow (L/s) | Suspended Sediment Flux (kg/d) W1E 19 Jul 99 |
|---|---|---|---|---|---|---|---|---|
| 138 | W1E-1 | 105 | 80 | 108 | 296 | 37.50 | 8.71 | 28.22 |
| 139 | W1E-2 | 105 | 99 | 109 | 300 | 40.40 | 9.35 | 32.63 |
| 140 | W1E-3 | 104 | 98 | 107 | 303 | 30.61 | 9.84 | 26.04 |
| 141 | W1E-4 | 103 | 97 | 108 | 310 | 51.55 | 11.06 | 49.25 |
| 142 | W1E-5 | 106 | 98 | 113 | 300 | 71.43 | 9.35 | 57.69 |
| 154 | W1E-6 | 104 | 99 | 109 | 295 | 50.51 | 8.55 | 37.33 |
| | | | | | Stage 6 (mm) | | | W1N 19 Jul 99 |
| 143 | W1N-1 | 103 | 47 | 172 | 118 | 1468.09 | 8.41 | 1066.92 |
| 144 | W1N-2 | 106 | 47 | 200 | 120 | 2000.00 | 8.59 | 1483.89 |
| 145 QA/QC | W1N-2 | 106 | 47 | 200 | 120 | 2000.00 | 8.59 | 1483.89 |
| 146 | W1N-3 | 103 | 42 | 139 | 122 | 857.14 | 9.23 | 683.78 |
| 147 | W1N-4 | 105 | 48 | 123 | 122 | 375.00 | 9.34 | 302.61 |
| 148 | W1N-5 | 107 | 50 | 114 | 129 | 140.00 | 9.73 | 117.68 |
| | | | | | Stage 1 (mm) | | | W1 19 Jul 99 |
| 149 | W1-1 | 105 | 55 | 170 | 124 | 1181.82 | 17.12 | 1748.24 |
| 150 | W1-2 | 105 | 98 | 129 | 129 | 244.90 | 17.94 | 379.50 |
| 151 | W1-3 | 105 | 94 | 118 | 135 | 138.30 | 19.08 | 227.95 |
| 152 | W1-4 | 106 | 99 | 117 | 141 | 111.11 | 20.40 | 195.83 |
| 153 | W1-5 | 107 | 99 | 116 | 135 | 90.91 | 19.08 | 149.84 |

**Table D-4. 19 Jul 1999 Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 15-Sep-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Stage 7 (mm) | Suspended Sediment Concentration (mg/l) | Flow (L/s) | Suspended Sediment Flux (kg/d) W1E 15 Sep 99 |
|---|---|---|---|---|---|---|---|---|
| 158 | W1E-1 | 105 | 166 | 109 | 299 | 24.10 | 9.19 | 19.12 |
| 159 QA/QC | W1E-1 | 105 | 166 | 109 | 299 | 24.10 | 9.19 | 19.12 |
| 160 | W1E-2 | 104 | 149 | 108 | 305 | 26.85 | 10.18 | 23.62 |
| 161 | W1E-3 | 106 | 199 | 110 | 310 | 20.10 | 11.06 | 19.21 |
| | | | | | Stage 6 (mm) | | | W1N 15 Sep 99 |
| 155 | W1N-1 | 103 | 100 | 109 | 105 | 60.00 | 7.01 | 36.32 |
| 156 | W1N-2 | 105 | 97 | 111 | 110 | 61.86 | 8.41 | 44.94 |
| 157 | W1N-3 | 106 | 97 | 111 | 114 | 51.55 | 8.89 | 39.61 |
| | | | | | Stage 1 (mm) | | | W1 15 Sep 99 |
| 162 | W1-1 | 103 | 159 | 108 | 117 | 31.45 | 16.19 | 43.99 |
| 163 | W1-2 | 104 | 164 | 109 | 127 | 30.49 | 17.59 | 46.35 |
| 164 | W1-3 | 105 | 160 | 109 | 135 | 25.00 | 19.08 | 41.21 |

**Table D-5. 15 Sep 1999 Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 27-Sep-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Stage 7 (mm) | Suspended Sediment Concentration (mg/l) | Flow (L/s) | Suspended Sediment Flux (kg/d) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | W1E 27 Sep 99 |
| 165 | W1E-3 | 104 | 198 | 106 | 280 | 10.10 | 6.42 | 5.61 |
| 166 | W1E-4 | 104 | 100 | 109 | 294 | 50.00 | 8.40 | 36.29 |
| 167 | W1E-5 | 107 | 100 | 109 | 302 | 20.00 | 9.68 | 16.72 |
| | | | | | Stage 6 (mm) | | | W1N 27 Sep 99 |
| 168 | W1N-3 | 105 | 100 | 110 | 102 | 50.00 | 8.87 | 38.30 |
| 169 | W1N-4 | 109 | 78 | 124 | 110 | 192.31 | 8.72 | 144.89 |
| 170 | W1N-5 | 106 | 78 | 120 | 120 | 179.49 | 8.44 | 130.82 |
| 171 | W1n-5 QA/QC | 105 | 78 | 120 | 120 | 192.31 | 8.44 | 140.17 |
| | | | | | Stage 1 (mm) | | | W1 27 Sep 99 |
| 172 | W1-3 | 104 | 100 | 107 | 107 | 30.00 | 15.29 | 39.63 |
| 173 | W1-4 | 106 | 100 | 119 | 124 | 130.00 | 17.12 | 192.31 |
| 174 | W1-5 | 104 | 89 | 110 | 130 | 67.42 | 18.11 | 105.50 |
| 187 | W1N Direct Rd Runof | 103 | 34 | 189 | | 2529.41 | | |
| 188 | W1n Above Rd | 106 | 83 | 108 | | 24.10 | | |
| 189 | W1N Head Waters | 108 | 98 | 113 | | 51.02 | | |
| 190 | W1E Head Waters | 102 | 95 | 104 | | 21.05 | | |

**Table D-6. 27 Sep 1999 Single Storm Data**

| Suspended Sediment analysis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| W1, Fort Jackson, SC | | | Date of event: | 28-Sep-99 | | Prepared by:REW | | |
| | | | | | | Date: 1 Oct 1999 | | Suspended |
| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Stage 7 (mm) | Suspended Sediment Concentration (mg/l) | Flow (L/s) | Sediment Flux (kg/d) |
| | | | | | | | | W1E 28 Sep 99 |
| 175 | W1E-1 | 105 | 98 | 110 | 280 | 51.02 | 6.42 | 28.31 |
| 176 | W1E-2 | 106 | 99 | 110 | 294 | 40.40 | 8.40 | 29.33 |
| 177 | W1E-3 | 105 | 100 | 110 | 302 | 50.00 | 9.68 | 41.80 |
| 178 | W1E-4 | 106 | 100 | 108 | 301 | 20.00 | 9.51 | 16.44 |
| | | | | | Stage 6 (mm) | | | W1N 28 Sep 99 |
| 179 | W1N-3 | 102 | 94 | 111 | 102 | 95.74 | 8.87 | 73.35 |
| 180 | W1N-4 | 105 | 100 | 112 | 110 | 70.00 | 8.72 | 52.74 |
| 181 | W1N-5 | 111 | 101 | 114 | 120 | 29.70 | 8.44 | 21.65 |
| | | | | | Stage 1 (mm) | | | W1 28 Sep 99 |
| 182 | W1-3 | 111 | 100 | 118 | 107 | 70.00 | 15.29 | 92.47 |
| 183 | W1-4 | 109 | 84 | 114 | 124 | 59.52 | 17.12 | 88.05 |
| 184 | W1-5 | 109 | 90 | 113 | 130 | 44.44 | 18.11 | 69.55 |
| 185 | W1N Below Rd Runof | 105 | 57 | 123 | | 315.79 | | |

**Table D-7. 28 Sep 1999 Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 4-Oct-99

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 1 (mm) | Flow (l/s) | Suspended Sediment Flux (kg/d) W1 4 Oct 99 |
|---|---|---|---|---|---|---|---|---|
| 191 | W1-1 | 105 | 153 | 106 | 6.54 | 85 | 15.06 | 8.51 |
| 192 | W1-2 | 109 | 134 | 117 | 59.70 | 105 | 15.17 | 78.24 |
| 193 QA/QC | W1-2 | 109 | 134 | 117 | 59.70 | 105 | 15.17 | 78.24 |
| 194 | W1-3 | 105 | 99 | 108 | 30.30 | 113 | 15.77 | 41.29 |
| 195 | W1-4 | 108 | 177 | 112 | 22.60 | 123 | 16.97 | 33.14 |
| 196 | W1-5 | 106 | 98 | 109 | 30.61 | 125 | 17.27 | 45.69 |
| 197 | W1-6 | 109 | 100 | 112 | 30.00 | 129 | 17.94 | 46.49 |
| 198 | W1-7 | 108 | 100 | 111 | 30.00 | 128 | 17.76 | 46.04 |
| | | | | | | Stage 7 (mm) | | W1E 4 Oct 99 |
| 205 | W1E-1 | 104 | 158 | 105 | 6.33 | 261 | 4.26 | 2.33 |
| 206 | W1E-2 | 104 | 159 | 107 | 18.87 | 281 | 6.55 | 10.68 |
| 207 QA/QC | W1E-2 | 104 | 159 | 107 | 18.87 | 281 | 6.55 | 10.68 |
| 208 | W1E-3 | 104 | 98 | 105 | 10.20 | 285 | 7.09 | 6.25 |
| 209 | W1E-4 | 104 | 100 | 105 | 10.00 | 294 | 8.40 | 7.26 |
| 210 | W1E-5 | 104 | 97 | 106 | 20.62 | 293 | 8.25 | 14.69 |
| 211 | W1E-6 | 102 | 98 | 104 | 20.41 | 298 | 9.03 | 15.91 |
| 212 | W1E-7 | 104 | 100 | 106 | 20.00 | 299 | 9.19 | 15.87 |
| | | | | | | Stage 6 (mm) | | W1N 16 Jun 99 |
| 199 | W1N-1 | 111 | 182 | 113 | 10.99 | 101 | 10.81 | 10.26 |
| 200 | W1N-2 | 109 | 70 | 135 | 371.43 | 102 | 8.62 | 276.48 |
| 201 | W1N-3 | 104 | 60 | 120 | 266.67 | 109 | 8.62 | 198.50 |
| 202 | W1N-4 | 104 | 100 | 111 | 70.00 | 112 | 7.37 | 44.57 |
| 203 | W1N-5 | 104 | 100 | 107 | 30.00 | 118 | 8.72 | 22.61 |
| 204 | W1N-6 | 103 | 95 | 105 | 21.05 | 112 | 8.25 | 15.00 |

**Table D-8. 4 Oct 1999 Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 10-Jan-00

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 1 (mm) | Flow (l/s) | SS Flux (kg/d) |
|---|---|---|---|---|---|---|---|---|
| 225 | W1-1 | 103 | 87 | 111 | 91.95 | 455 | 340.88 | 2708.23 |
| 226 | W1-2 | 105 | 90 | 113 | 88.89 | 460 | 349.97 | 2687.79 |
| 242 | W1-3 | 102 | 62 | 110 | 129.03 | 465 | 359.19 | 4004.39 |
| 228 | W1-4 | 104 | 71 | 119 | 211.27 | 385 | 226.72 | 4138.40 |
| 229 | W1-5 | 105 | 78 | 119 | 179.49 | 280 | 101.43 | 1572.96 |
| 230 | W1-6 | 105 | 86 | 113 | 93.02 | 205 | 45.70 | 367.33 |
| 231 | W1-7 | 104 | 98 | 106 | 20.41 | 157 | 24.80 | 43.74 |
| | | | | | | Stage 7 (mm) | | |
| 232 | W1E-1 | 104 | 79 | 111 | 88.61 | 564 | 227.50 | 1741.70 |
| 233 QA/QC | W1E-1 | 104 | 79 | 111 | 88.61 | 564 | 227.50 | 1741.70 |
| 234 | W1E-2 | 106 | 70 | 112 | 85.71 | 568 | 235.93 | 1747.19 |
| 235 | W1E-3 | 104 | 63 | 113 | 142.86 | 574 | 249.03 | 3073.71 |
| 236 | W1E-4 | 105 | 51 | 118 | 254.90 | 493 | 113.88 | 2507.99 |
| 237 | W1E-5 | 105 | 51 | 114 | 176.47 | 412 | 45.24 | 689.74 |
| 238 | W1E-6 | 102 | 62 | 108 | 96.77 | 335 | 15.61 | 130.50 |
| 239 | W1E-7 | 104 | 178 | 108 | 22.47 | 310 | 10.47 | 20.33 |

**Table D-9. 10 Jan 2000 Single Storm Data**

Suspended Sediment analysis

W1, Fort Jackson, SC — Date of event: 10-Jan-00

| Filter Number | Sample Number | Filter Weight (mg) | Sample Volume (ml) | Filter Plus Dried Residue Weight (mg) | Suspended Sediment Concentration (mg/l) | Stage 6 (mm) | Flow (l/s) | SS Flux (kg/d) |
|---|---|---|---|---|---|---|---|---|
| 240 | W1N-1 | 104 | 70 | 111 | 100.00 | 395 | 113.38 | 979.58 |
| 241 | W1N-2 | 104 | 85 | 111 | 82.35 | 400 | 114.05 | 811.48 |
| 227 | W1N-3 | 105 | 90 | 113 | 88.89 | 406 | 110.16 | 846.05 |
| 243 | W1N-4 | 104 | 72 | 116 | 166.67 | 320 | 112.84 | 1624.90 |
| 244 | W1N-5 | 103 | 59 | 111 | 135.59 | 210 | 56.19 | 658.32 |
| 245 | W1N-6 | 103 | 100 | 110 | 70.00 | 133 | 30.10 | 182.02 |
| 246 | W1N-7 | 103 | 100 | 104 | 10.00 | 116 | 14.33 | 12.38 |
| | | | | | | | | |
| 247 | W1N-Dam | 103 | 96 | 107 | 41.67 | | | |
| 248 | W1Nabove Rd | 104 | 93 | 109 | 53.76 | | | |
| 249 | Brm-19 OHG Cul\ | 102 | 64 | 145 | 671.88 | | | |

**Table D-9 Continued. 12 Jan 2000 Single Storm Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Suspen Sed Concentration (mg/l) | Stage (6) (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) | Elapsed Time (min) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1N 12-Feb-99 |
| 12-Feb-99 | 1500 | 0.03 | 2 | 131.15 | 126 | 6.22 | 70.53 | 2 | 5.71 | 64.71 |
| 12-Feb-99 | 1519 | 0.35 | 5 | 25.86 | 128 | 6.88 | 15.38 | 21 | 6.32 | 14.11 |
| 12-Feb-99 | 1537 | 0.65 | 8 | 32.26 | 126 | 7.11 | 19.82 | 39 | 6.52 | 18.18 |
| 12-Feb-99 | 1553 | 0.92 | 11 | 8.77 | 129 | 6.75 | 5.11 | 55 | 6.19 | 4.69 |
| 12-Feb-99 | 1628 | 1.50 | 14 | 6.99 | 125 | 6.92 | 4.18 | 90 | 6.35 | 3.84 |
| 12-Feb-99 | 1647 | 1.82 | 17 | 6.10 | 122 | 6.89 | 3.63 | 109 | 6.32 | 3.33 |
| 12-Feb-99 | 1701 | 2.05 | 20 | 13.89 | 121 | 6.52 | 7.83 | 123 | 5.98 | 7.18 |
| 12-Feb-99 | 1731 | 2.55 | 23 | 13.25 | 121 | 6.25 | 7.15 | 153 | 5.73 | 6.56 |
| | | | | | 143 | 19.00 | | | | W1N 16-Jun-99 |
| 16-Jun-99 | 1619 | 0.00 | 1 | 2161.29 | 145 | 20.32 | 3793.60 | 0 | 18.64 | 3480.37 |
| 16-Jun-99 | 1624 | 0.12 | 2 | 854.17 | 150 | 26.44 | 1951.45 | 7 | 24.26 | 1790.32 |
| 16-Jun-99 | 1629 | 0.22 | 3 | 451.22 | 160 | 31.36 | 1222.50 | 13 | 28.77 | 1121.56 |
| 16-Jun-99 | 1634 | 0.33 | 4 | 255.32 | 165 | 33.86 | 746.96 | 20 | 31.07 | 685.29 |
| 16-Jun-99 | 1639 | 0.45 | 5 | 244.44 | 170 | 30.55 | 645.22 | 27 | 28.03 | 591.94 |
| 16-Jun-99 | 1644 | 0.57 | 6 | 265.82 | 175 | 29.98 | 688.48 | 34 | 27.50 | 631.64 |
| 16-Jun-99 | 1650 | 0.68 | 7 | 333.33 | 178 | 28.47 | 820.02 | 41 | 26.12 | 752.31 |
| 16-Jun-99 | 1656 | 0.80 | 8 | 295.77 | 178 | 28.23 | 721.54 | 48 | 25.90 | 661.96 |
| 16-Jun-99 | 1714 | 0.93 | 9 | 259.26 | 162 | 26.46 | 592.61 | 56 | 24.27 | 543.68 |
| 16-Jun-99 | 1724 | 1.05 | 10 | 181.82 | 155 | 25.71 | 403.83 | 63 | 23.58 | 370.49 |
| 16-Jun-99 | 1745 | 1.17 | 11 | 70.71 | 150 | 24.94 | 152.38 | 70 | 22.88 | 139.79 |
| 16-Jun-99 | 1804 | 1.28 | 12 | 50.00 | 149 | 25.45 | 109.96 | 77 | 23.35 | 100.88 |
| 16-Jun-99 | 1822 | 1.40 | 13 | 40.40 | 142 | 26.46 | 92.36 | 84 | 24.27 | 84.73 |
| | | | | | | | | | | W1N 25-Jun-99 |
| 25-Jun-99 | 839 | 0.00 | 1 | 43.01 | 106 | 6.47 | 24.03 | 0 | 5.93 | 22.04 |
| 25-Jun-99 | 904 | 0.42 | 2 | 97.74 | 109 | 6.49 | 54.81 | 25 | 5.95 | 50.28 |
| 25-Jun-99 | 915 | 0.60 | 3 | 67.67 | 115 | 6.65 | 38.89 | 36 | 6.10 | 35.68 |
| 25-Jun-99 | 925 | 0.77 | 4 | 20.83 | 114 | 6.62 | 11.92 | 46 | 6.08 | 10.94 |

**Table 10. W1 N Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Suspen Sed Concentration (mg/l) | Stage (6) (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) | Elapsed Time (min) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1N 19-Jul-99 |
| 19-Jul-99 | 1445 | 0.00 | 1 | 1468.09 | 118 | 8.41 | 1066.92 | 0 | 7.72 | 978.83 |
| 19-Jul-99 | 1450 | 0.08 | 2 | 2000.00 | 120 | 8.59 | 1483.89 | 5 | 7.88 | 1361.36 |
| 19-Jul-99 | 1455 | 0.17 | 3 | 857.14 | 122 | 9.23 | 683.78 | 10 | 8.47 | 627.33 |
| 19-Jul-99 | 1500 | 0.25 | 4 | 375.00 | 122 | 9.34 | 302.61 | 15 | 8.57 | 277.63 |
| 19-Jul-99 | 1510 | 0.42 | 5 | 140.00 | 129 | 9.73 | 117.68 | 25 | 8.93 | 107.97 |
| | | | | | | | | | | W1N 15-Sep-99 |
| 15-Sep-99 | 1749 | 0.00 | 1 | 60.00 | 105 | 7.01 | 36.32 | 0 | 6.43 | 33.32 |
| 15-Sep-99 | 1826 | 0.62 | 2 | 61.86 | 110 | 8.41 | 44.94 | 37 | 7.71 | 41.23 |
| 15-Sep-99 | 1900 | 1.18 | 3 | 51.55 | 114 | 8.89 | 39.61 | 71 | 8.16 | 36.34 |
| | | | | | | | | | | W1n 27-Sep-99 |
| 27-Sep-99 | 1135 | 0.00 | 1 | 50.00 | 102 | 8.87 | 38.30 | 0 | 8.13 | 35.14 |
| 27-Sep-99 | 1142 | 0.12 | 2 | 192.31 | 110 | 8.72 | 144.89 | 7 | 8.00 | 132.93 |
| 27-Sep-99 | 1156 | 0.35 | 3 | 179.49 | 120 | 8.44 | 130.82 | 21 | 7.74 | 120.02 |
| W1N Rd | 1140 | | | 2529.41 | | | | 5 | 2529.41 | |
| W1N Above I | 1140 | | | 24.10 | | | | 5 | 24.10 | |
| W1N Head W | 1205 | | | 51.02 | | | | 30 | 51.02 | |
| | | | | | | | | | | W1N 28-Sep-99 |
| 28-Sep-99 | 1402 | 0.00 | 1 | 95.74 | 102 | 8.87 | 73.35 | 0 | 8.13 | 67.29 |
| 28-Sep-99 | 1415 | 0.22 | 2 | 70.00 | 110 | 8.72 | 52.74 | 13 | 8.00 | 48.39 |
| 28-Sep-99 | 1436 | 0.57 | 3 | 29.70 | 120 | 8.44 | 21.65 | 34 | 7.74 | 19.86 |
| W1N Rd | 1405 | 0.05 | | 315.79 | | | | 3 | 315.79 | |

**Table 10 Continued. W1 N Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Suspen Sed Concentration (mg/l) | Stage (6) (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) | Elapsed Time (min) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W 1N 4 Oct 99 |
| 4-Oct-99 | 1322 | 0.00 | 1 | 10.99 | 101 | 10.81 | 10.26 | 0 | 9.91 | 9.41 |
| 4-Oct-99 | 1327 | 0.08 | 2 | 371.43 | 102 | 8.62 | 276.48 | 5 | 7.90 | 253.65 |
| 4-Oct-99 | 1338 | 0.27 | 3 | 266.67 | 109 | 8.62 | 198.50 | 16 | 7.90 | 182.11 |
| 4-Oct-99 | 1357 | 0.58 | 4 | 70.00 | 112 | 7.37 | 44.57 | 35 | 6.76 | 40.89 |
| 4-Oct-99 | 1422 | 1.00 | 5 | 30.00 | 118 | 8.72 | 22.61 | 60 | 8.00 | 20.75 |
| 4-Oct-99 | 1502 | 1.67 | 6 | 21.05 | 112 | 8.25 | 15.00 | 100 | 7.57 | 13.76 |
| Date | Time | Elapsed Time (dec hrs) | Sample | Suspen Sed Concentration (mg/l) | Stage (6) (mm) | Flow (L/s) | Suspended Sediment Flux (kg/d) | Elapsed Time (min) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) W1N 10 Jan 00 |
| 10-Jan-00 | 0923 | 0.00 | 1 | 100.00 | 395 | 113.38 | 979.58 | 0 | 104.02 | 898.69 |
| 10-Jan-00 | 0940 | 0.28 | 2 | 82.35 | 400 | 114.05 | 811.48 | 17 | 104.63 | 744.48 |
| 10-Jan-00 | 0955 | 0.53 | 3 | 88.89 | 406 | 110.16 | 846.05 | 32 | 101.07 | 776.19 |
| 10-Jan-00 | 1105 | 1.42 | 4 | 166.67 | 320 | 112.84 | 1624.90 | 85 | 103.52 | 1490.74 |
| 10-Jan-00 | 1200 | 2.42 | 5 | 135.59 | 210 | 56.19 | 658.32 | 145 | 51.55 | 603.96 |
| 10-Jan-00 | 1315 | 3.67 | 6 | 70.00 | 133 | 30.10 | 182.02 | 220 | 27.61 | 166.99 |
| 10-Jan-00 | 1545 | 6.17 | 7 | 10.00 | 116 | 14.33 | 12.38 | 370 | 13.15 | 11.36 |
| 10-Jan-00 | 0906 | W1N Dam | | 41.67 | | | | -17 | 41.67 | |
| 10-Jan-00 | 0932 | W1N Rd | | 53.76 | | | | 9 | 53.76 | |

**Table 10 Continued. W1 N Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Flow (L/s) | Suspen Sed Concentration (mg/l) | Stage (7) (mm) | Elapsed Time (min) | Suspended Sediment Flux (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1E 12 Feb 99 |
| 12-Feb-99 | 1502 | 0.07 | 3 | 11.05 | 34.29 | 310 | 4 | 32.73 | 2.01 | 5.94 |
| 12-Feb-99 | 1520 | 0.37 | 6 | 11.41 | 20.98 | 312 | 22 | 20.68 | 2.07 | 3.75 |
| 12-Feb-99 | 1538 | 0.67 | 9 | 11.97 | 23.04 | 315 | 40 | 23.82 | 2.17 | 4.32 |
| 12-Feb-99 | 1554 | 0.93 | 12 | 12.54 | 25.16 | 318 | 56 | 27.25 | 2.28 | 4.95 |
| 12-Feb-99 | 1628 | 1.50 | 15 | 12.16 | 20.55 | 316 | 90 | 21.58 | 2.21 | 3.92 |
| 12-Feb-99 | 1648 | 1.83 | 18 | 11.60 | 22.22 | 313 | 110 | 22.26 | 2.10 | 4.04 |
| 12-Feb-99 | 1702 | 2.07 | 21 | 11.41 | 10.75 | 312 | 124 | 10.60 | 2.07 | 1.92 |
| 12-Feb-99 | 1732 | 2.57 | 24 | 10.87 | 11.49 | 309 | 154 | 10.80 | 1.97 | 1.96 |
| | | | | | | | | | | W1E 16 Jun 99 |
| 16-Jun-99 | 1620 | 0.02 | 1 | 13.94 | 61.73 | 325 | 1 | 74.33 | 2.53 | 13.49 |
| 16-Jun-99 | 1625 | 0.13 | 2 | 14.98 | 157.89 | 330 | 8 | 204.33 | 2.72 | 37.08 |
| 16-Jun-99 | 1630 | 0.23 | 3 | 17.19 | 240.00 | 340 | 14 | 356.37 | 3.12 | 64.68 |
| 16-Jun-99 | 1635 | 0.35 | 4 | 17.65 | 267.61 | 342 | 21 | 408.03 | 3.20 | 74.05 |
| 16-Jun-99 | 1640 | 0.47 | 5 | 17.42 | 307.69 | 341 | 28 | 462.99 | 3.16 | 84.03 |
| 16-Jun-99 | 1645 | 0.58 | 6 | 17.42 | 394.74 | 341 | 35 | 593.97 | 3.16 | 107.80 |
| 16-Jun-99 | 1651 | 0.70 | 7 | 18.35 | 369.86 | 345 | 42 | 586.46 | 3.33 | 106.44 |
| 16-Jun-99 | 1657 | 0.82 | 8 | 18.59 | 279.41 | 346 | 49 | 448.79 | 3.37 | 81.45 |
| 16-Jun-99 | 1715 | 0.95 | 9 | 19.81 | 154.93 | 351 | 57 | 265.12 | 3.59 | 48.12 |
| 16-Jun-99 | 1724 | 1.07 | 10 | 20.56 | 140.85 | 354 | 64 | 250.14 | 3.73 | 45.40 |
| 16-Jun-99 | 1745 | 1.17 | 11 | 21.32 | 144.93 | 357 | 70 | 266.96 | 3.87 | 48.45 |
| 16-Jun-99 | 1804 | 1.28 | 12 | 20.81 | 137.93 | 355 | 77 | 247.98 | 3.78 | 45.01 |
| 16-Jun-99 | 1822 | 1.40 | 13 | 19.81 | 76.92 | 351 | 84 | 131.63 | 3.59 | 23.89 |
| 16-Jun-99 | 1830 | 1.55 | 14 | 18.35 | 53.33 | 345 | 93 | 84.57 | 3.33 | 15.35 |
| | | | | | | | | | | W1E 25 Jun 99 |
| 25-Jun-99 | 0852 | 0.22 | 1 | 8.40 | 30.00 | 294 | 13 | 21.77 | 1.52 | 3.95 |
| 25-Jun-99 | 904 | 0.42 | 2 | 8.87 | 41.24 | 297 | 25 | 31.59 | 1.61 | 5.73 |
| 25-Jun-99 | 915 | 0.60 | 3 | 9.03 | 40.00 | 298 | 36 | 31.19 | 1.64 | 5.66 |
| 25-Jun-99 | 925 | 0.77 | 4 | 9.35 | 40.00 | 300 | 46 | 32.31 | 1.70 | 5.86 |

**Table 11. W1 E Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Flow (L/s) | Suspen Sed Concentration (mg/l) | Stage (7) (mm) | Elapsed Time (min) | Suspended Sediment Flu) (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1E 19 Jul 99 |
| 19-Jul-99 | 1446 | 0.02 | 1 | 8.71 | 37.50 | 296 | 1 | 28.22 | 1.58 | 5.12 |
| 19-Jul-99 | 1451 | 0.10 | 2 | 9.35 | 40.40 | 300 | 6 | 32.63 | 1.70 | 5.92 |
| 19-Jul-99 | 1456 | 0.18 | 3 | 9.84 | 30.61 | 303 | 11 | 26.04 | 1.79 | 4.73 |
| 19-Jul-99 | 1501 | 0.27 | 4 | 11.06 | 51.55 | 310 | 16 | 49.25 | 2.01 | 8.94 |
| 19-Jul-99 | 1511 | 0.42 | 5 | 9.35 | 71.43 | 300 | 25 | 57.69 | 1.70 | 10.47 |
| 19-Jul-99 | 1531 | 0.77 | 6 | 8.55 | 50.51 | 295 | 46 | 37.33 | 1.55 | 6.77 |
| | | | | | | | | | | W1E 15 Sep 99 |
| 15-Sep-99 | 1751 | 0.03 | 1 | 9.19 | 24.10 | 299 | 2 | 19.12 | 1.67 | 3.47 |
| 15-Sep-99 | 1826 | 0.62 | 2 | 10.18 | 26.85 | 305 | 37 | 23.62 | 1.85 | 4.29 |
| 15-Sep-99 | 1901 | 1.20 | 3 | 11.06 | 20.10 | 310 | 72 | 19.21 | 2.01 | 3.49 |
| | | | | | | | | | | W1E 27 Sep 99 |
| 27-Sep-99 | 1138 | 0.00 | 1 | 6.42 | 10.10 | 280 | 0 | 5.61 | 1.17 | 1.02 |
| 27-Sep-99 | 1151 | 0.22 | 2 | 8.40 | 50.00 | 294 | 13 | 36.29 | 1.52 | 6.59 |
| 27-Sep-99 | 1255 | 1.28 | 3 | 9.68 | 20.00 | 302 | 77 | 16.72 | 1.76 | 3.03 |
| | | | | | | | | | | W1E 28 Sep 99 |
| 28-Sep-99 | 1402 | 0.00 | 1 | 6.42 | 51.02 | 280 | 0 | 28.31 | 1.17 | 5.14 |
| 28-Sep-99 | 1415 | 0.22 | 2 | 8.40 | 40.40 | 294 | 13 | 29.33 | 1.52 | 5.32 |
| 28-Sep-99 | 1436 | 0.57 | 3 | 9.68 | 50.00 | 302 | 34 | 41.80 | 1.76 | 7.59 |
| 28-Sep-99 | 1441 | 0.65 | 4 | 9.51 | 20.00 | 301 | 39 | 16.44 | 1.73 | 2.98 |

**Table 11 Continued. W1 E Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Flow (L/s) | Suspen Sed Concentration (mg/l) | Stage (7) (mm) | Elapsed Time (min) | Suspended Sediment Flu) (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1E 4 Oct 99 |
| 4-Oct-99 | 1322 | 0.00 | 1 | 4.26 | 6.33 | 261 | 0 | 2.33 | 0.77 | 0.42 |
| 4-Oct-99 | 1348 | 0.43 | 2 | 6.55 | 18.87 | 281 | 26 | 10.68 | 1.19 | 1.94 |
| 4-Oct-99 | 1400 | 0.63 | 3 | 7.09 | 10.20 | 285 | 38 | 6.25 | 1.29 | 1.13 |
| 4-Oct-99 | 1422 | 1.00 | 4 | 8.40 | 10.00 | 294 | 60 | 7.26 | 1.52 | 1.32 |
| 4-Oct-99 | 1436 | 1.23 | 5 | 8.25 | 20.62 | 293 | 74 | 14.69 | 1.50 | 2.67 |
| 4-Oct-99 | 1502 | 1.83 | 6 | 9.03 | 20.41 | 298 | 110 | 15.91 | 1.64 | 2.89 |
| 4-Oct-99 | 1517 | 2.08 | 7 | 9.19 | 20.00 | 299 | 125 | 15.87 | 1.67 | 2.88 |
| | | | | | | | | | | W1E 10 Jan 00 |
| 10-Jan-00 | 924 | 0.02 | 1 | 227.50 | 88.61 | 564 | 1 | 1741.70 | 41.29 | 316.10 |
| 10-Jan-00 | 941 | 0.30 | 2 | 235.93 | 85.71 | 568 | 18 | 1747.19 | 42.82 | 317.10 |
| 10-Jan-00 | 956 | 0.55 | 3 | 249.03 | 142.86 | 574 | 33 | 3073.71 | 45.20 | 557.84 |
| 10-Jan-00 | 1106 | 1.43 | 4 | 113.88 | 254.90 | 493 | 86 | 2507.99 | 20.67 | 455.17 |
| 10-Jan-00 | 1201 | 2.43 | 5 | 45.24 | 176.47 | 412 | 146 | 689.74 | 8.21 | 125.18 |
| 10-Jan-00 | 1315 | 3.68 | 6 | 15.61 | 96.77 | 335 | 221 | 130.50 | 2.83 | 23.68 |
| 10-Jan-00 | 1546 | 6.18 | 7 | 10.47 | 22.47 | 310 | 371 | 20.33 | 1.90 | 3.69 |
| 10-Jan-00 | 1032 | Brm19 OHG Cul | | 671.88 | | | | 69.00 | 671.88 | |

**Table 11 Continued. W1 E Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Elapsed Time (min) | Flow (L/s) | Susp Sed Concentration (mg/l) | Stage (1) (mm) | Suspended Sediment Flux (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1 12 Feb 99 |
| 12-Feb-99 | 1458 | 0.00 | 1 | 0 | 17.27 | 57.69 | 125 | 86.10 | 2.62 | 13.05 |
| 12-Feb-99 | 1518 | 0.33 | 2 | 20 | 18.30 | 32.89 | 131 | 52.00 | 2.77 | 7.88 |
| 12-Feb-99 | 1535 | 0.62 | 3 | 37 | 19.08 | 27.40 | 135 | 45.16 | 2.89 | 6.84 |
| 12-Feb-99 | 1551 | 0.88 | 4 | 53 | 19.28 | 18.75 | 136 | 31.24 | 2.92 | 4.73 |
| 12-Feb-99 | 1625 | 1.45 | 5 | 87 | 19.08 | 20.00 | 135 | 32.97 | 2.89 | 4.99 |
| 12-Feb-99 | 1645 | 1.78 | 6 | 107 | 18.48 | 29.70 | 132 | 47.44 | 2.80 | 7.19 |
| 12-Feb-99 | 1700 | 2.03 | 7 | 122 | 17.94 | 20.20 | 129 | 31.31 | 2.72 | 4.74 |
| 12-Feb-99 | 1730 | 2.53 | 8 | 152 | 17.12 | 9.90 | 124 | 14.65 | 2.59 | 2.22 |
| | | | | | | | | | | W1 16-Jun-99 |
| 16-Jun-99 | 1630 | 0.23 | 1 | 14 | 34.25 | 521.74 | 182 | 1544.00 | 5.19 | 233.94 |
| 16-Jun-99 | 1637 | 0.35 | 2 | 21 | 41.42 | 313.25 | 197 | 1121.05 | 6.28 | 169.86 |
| 16-Jun-99 | 1642 | 0.47 | 3 | 28 | 48.54 | 260.87 | 210 | 1094.14 | 7.36 | 165.78 |
| 16-Jun-99 | 1649 | 0.58 | 4 | 35 | 51.51 | 301.37 | 215 | 1341.20 | 7.80 | 203.21 |
| 16-Jun-99 | 1656 | 0.70 | 5 | 42 | 47.97 | 353.85 | 209 | 1466.43 | 7.27 | 222.19 |
| 16-Jun-99 | 1703 | 0.82 | 6 | 49 | 47.39 | 338.24 | 208 | 1384.99 | 7.18 | 209.85 |
| 16-Jun-99 | 1710 | 0.93 | 7 | 56 | 46.82 | 260.27 | 207 | 1052.98 | 7.09 | 159.54 |
| 16-Jun-99 | 1717 | 1.05 | 8 | 63 | 46.82 | 208.96 | 207 | 845.36 | 7.09 | 128.09 |
| 16-Jun-99 | 1724 | 1.17 | 9 | 70 | 46.26 | 189.19 | 206 | 756.20 | 7.01 | 114.58 |
| 16-Jun-99 | 1731 | 1.28 | 10 | 77 | 46.26 | 157.14 | 206 | 628.11 | 7.01 | 95.17 |
| 16-Jun-99 | 1738 | 1.40 | 11 | 84 | 46.26 | 126.76 | 206 | 506.67 | 7.01 | 76.77 |
| 16-Jun-99 | 1745 | 1.52 | 12 | 91 | 46.26 | 150.68 | 206 | 602.29 | 7.01 | 91.26 |
| 16-Jun-99 | 1752 | 1.63 | 13 | 98 | 45.70 | 82.19 | 205 | 324.56 | 6.92 | 49.18 |
| 16-Jun-99 | 1759 | 1.75 | 14 | 105 | 45.15 | 121.21 | 204 | 472.85 | 6.84 | 71.64 |
| 16-Jun-99 | 1806 | 1.87 | 15 | 112 | 42.99 | 112.36 | 200 | 417.33 | 6.51 | 63.23 |
| 16-Jun-99 | 1813 | 1.98 | 16 | 119 | 41.42 | 108.70 | 197 | 388.99 | 6.28 | 58.94 |
| 16-Jun-99 | 1820 | 2.10 | 17 | 126 | 40.91 | 94.74 | 196 | 334.84 | 6.20 | 50.73 |
| 16-Jun-99 | 1827 | 2.22 | 18 | 133 | 39.40 | 74.47 | 193 | 253.49 | 5.97 | 38.41 |
| 16-Jun-99 | 1834 | 2.33 | 19 | 140 | 38.91 | 72.29 | 192 | 243.00 | 5.89 | 36.82 |

**Table 12. W1 Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Elapsed Time (min) | Flow (L/s) | Susp Sed Concentration (mg/l) | Stage (1) (mm) | Suspended Sediment Flu) (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1 25 Jun 99 |
| 25-Jun-99 | 849 | 0.17 | 1 | 10 | 14.87 | 36.76 | 95 | 47.22 | 2.25 | 7.15 |
| 25-Jun-99 | 0907 | 0.47 | 2 | 28 | 15.36 | 50.00 | 108 | 66.34 | 2.33 | 10.05 |
| 25-Jun-99 | 0917 | 0.63 | 3 | 38 | 15.68 | 38.46 | 112 | 52.10 | 2.38 | 7.89 |
| 25-Jun-99 | 0928 | 0.82 | 4 | 49 | 15.97 | 50.00 | 115 | 69.00 | 2.42 | 10.45 |
| | | | | | | | | | | W1 19 Jul 99 |
| 19-Jul-99 | 1450 | 0.08 | 1 | 5 | 17.12 | 1181.82 | 124 | 1748.24 | 2.59 | 264.89 |
| 19-Jul-99 | 1500 | 0.25 | 2 | 15 | 17.94 | 244.90 | 129 | 379.50 | 2.72 | 57.50 |
| 19-Jul-99 | 1508 | 0.38 | 3 | 23 | 19.08 | 138.30 | 135 | 227.95 | 2.89 | 34.54 |
| 19-Jul-99 | 1518 | 0.55 | 4 | 33 | 20.40 | 111.11 | 141 | 195.83 | 3.09 | 29.67 |
| 19-Jul-99 | 1528 | 0.72 | 5 | 43 | 19.08 | 90.91 | 135 | 149.84 | 2.89 | 22.70 |
| | | | | | | | | | | W1 15 Sep 99 |
| 15-Sep-99 | 1752 | 0.05 | 1 | 3 | 16.19 | 31.45 | 117 | 43.99 | 2.45 | 6.67 |
| 15-Sep-99 | 1828 | 0.67 | 2 | 40 | 17.59 | 30.49 | 127 | 46.35 | 2.67 | 7.02 |
| 15-Sep-99 | 1902 | 1.23 | 3 | 74 | 19.08 | 25.00 | 135 | 41.21 | 2.89 | 6.24 |
| | | | | | | | | | | W1 27 Sep 99 |
| 27-Sep-99 | 1134 | 0.00 | 1 | 0 | 15.29 | 30.00 | 107 | 39.63 | 2.32 | 6.00 |
| 27-Sep-99 | 1149 | 0.25 | 2 | 15 | 17.12 | 130.00 | 124 | 192.31 | 2.59 | 29.14 |
| 27-Sep-99 | 1159 | 0.42 | 3 | 25 | 18.11 | 67.42 | 130 | 105.50 | 2.74 | 15.99 |
| | | | | | | | | | | W1 28 Sep 99 |
| 28-Sep-99 | 1403 | 0.00 | 1 | 0 | 15.29 | 70.00 | 107 | 92.47 | 2.32 | 14.01 |
| 28-Sep-99 | 1417 | 0.23 | 2 | 14 | 17.12 | 59.52 | 124 | 88.05 | 2.59 | 13.34 |
| 28-Sep-99 | 1431 | 0.47 | 3 | 28 | 18.11 | 44.44 | 130 | 69.55 | 2.74 | 10.54 |

**Table 12 Continued. W1 Unit Flux, Unit Flow, and Hydrograph Data**

| Date | Time | Elapsed Time (dec hrs) | Sample | Elapsed Time (min) | Flow (L/s) | Susp Sed Concentration (mg/l) | Stage (1) (mm) | Suspended Sediment Flu› (kg/d) | Unit Flow (L/s/km2) | Unit Suspended Sediment Flux (kg/d/km2) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | W1 4 Oct 99 |
| 4-Oct-99 | 1322 | 0.00 | 1 | 0 | 15.06 | 6.54 | 85 | 8.51 | 2.28 | 1.29 |
| 4-Oct-99 | 1348 | 0.43 | 2 | 26 | 15.17 | 59.70 | 105 | 78.24 | 2.30 | 11.85 |
| 4-Oct-99 | 1400 | 0.63 | 3 | 38 | 15.17 | 59.70 | 105 | 78.24 | 2.30 | 11.85 |
| 4-Oct-99 | 1422 | 1.00 | 4 | 60 | 15.77 | 30.30 | 113 | 41.29 | 2.39 | 6.26 |
| 4-Oct-99 | 1436 | 1.23 | 5 | 74 | 16.97 | 22.60 | 123 | 33.14 | 2.57 | 5.02 |
| 4-Oct-99 | 1502 | 1.83 | 6 | 110 | 17.27 | 30.61 | 125 | 45.69 | 2.62 | 6.92 |
| 4-Oct-99 | 1517 | 2.08 | 7 | 125 | 17.94 | 30.00 | 129 | 46.49 | 2.72 | 7.04 |
| | | | | | | | | | | W1 10 Jan 2000 |
| 10-Jan-00 | 0923 | 0.03 | 1 | 2 | 340.88 | 91.95 | 455 | 2708.23 | 51.65 | 410.34 |
| 10-Jan-00 | 0940 | 0.32 | 2 | 19 | 349.97 | 88.89 | 460 | 2687.79 | 53.03 | 407.24 |
| 10-Jan-00 | 0955 | 0.57 | 3 | 34 | 359.19 | 129.03 | 465 | 4004.39 | 54.42 | 606.73 |
| 10-Jan-00 | 1105 | 1.45 | 4 | 87 | 226.72 | 211.27 | 385 | 4138.40 | 34.35 | 627.03 |
| 10-Jan-00 | 1200 | 2.45 | 5 | 147 | 101.43 | 179.49 | 280 | 1572.96 | 15.37 | 238.33 |
| 10-Jan-00 | 1315 | 3.70 | 6 | 222 | 45.70 | 93.02 | 205 | 367.33 | 6.92 | 55.66 |
| 10-Jan-00 | 1545 | 6.20 | 7 | 372 | 24.80 | 20.41 | 157 | 43.74 | 3.76 | 6.63 |

**Table 12 Continued. W1 Unit Flux, Unit Flow, and Hydrograph Data**

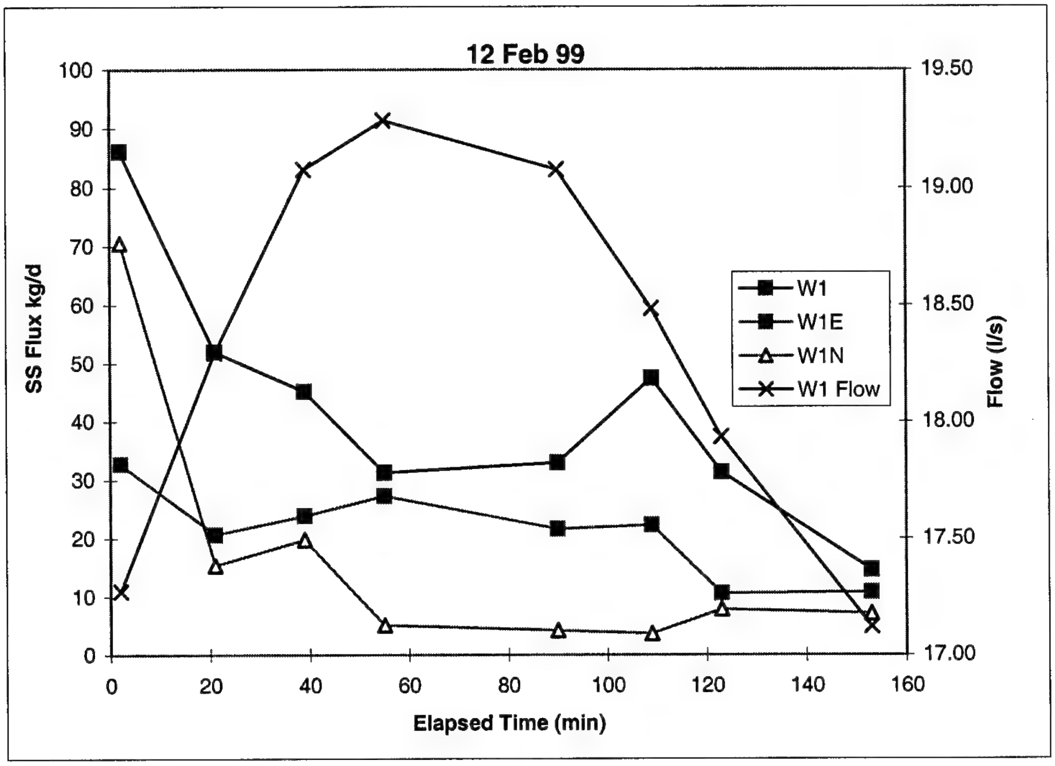



**Figure D-1. Single Storm Event**

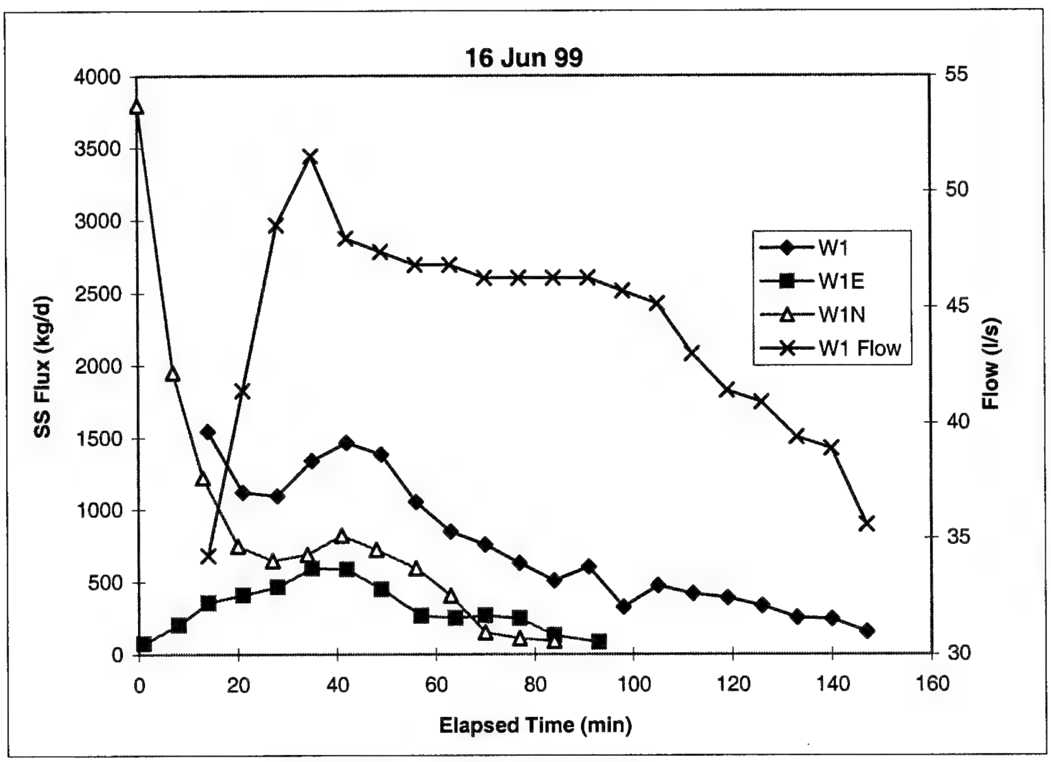



**Figure D-2. Single Storm Event**

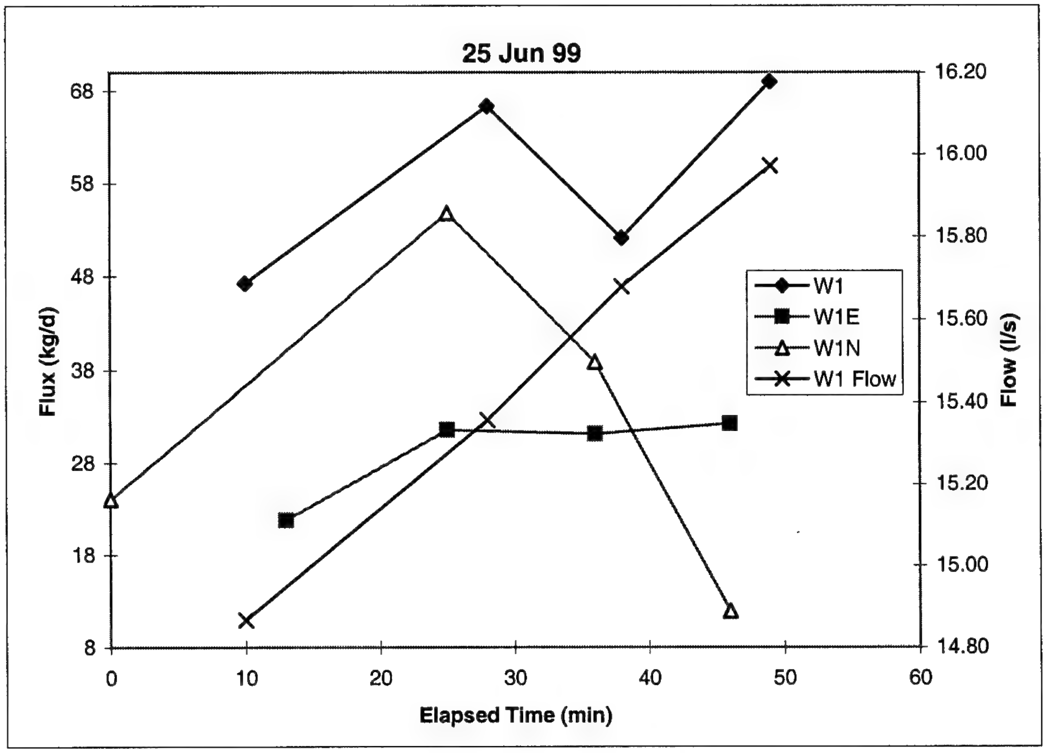



**Figure D-3. Single Storm Event**

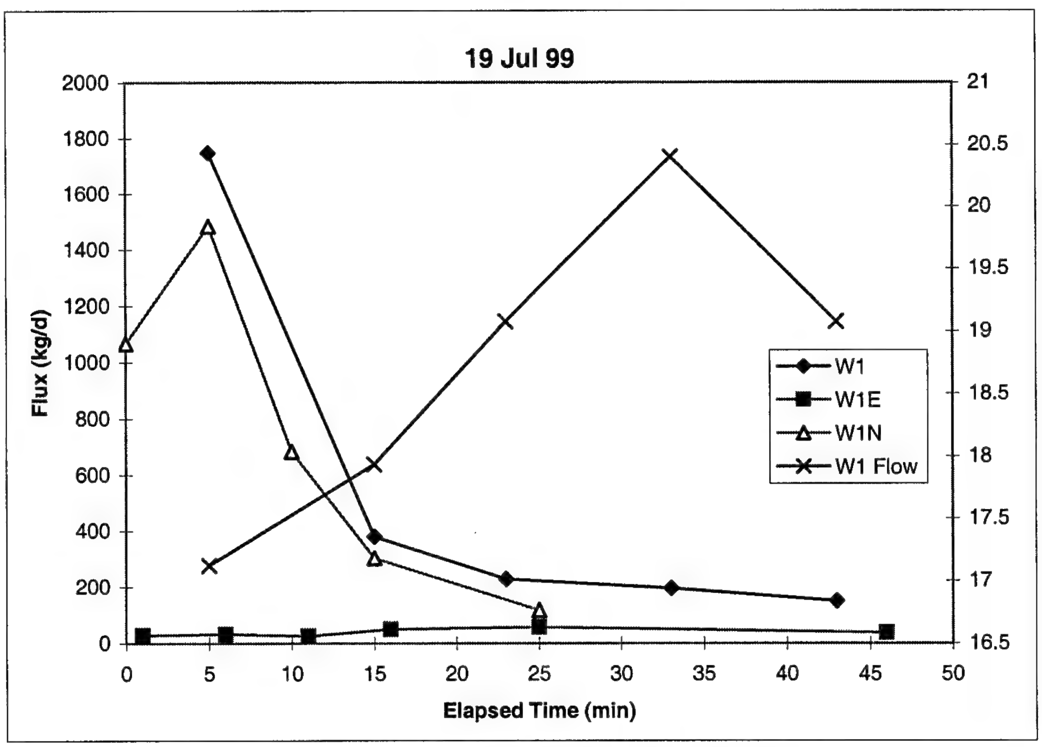



**Figure D-4. Single Storm Event**

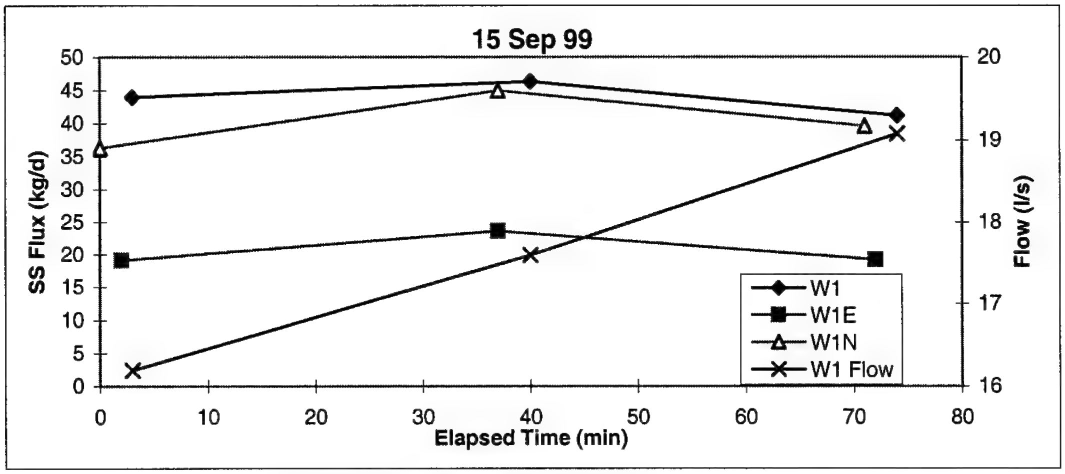



Figure D-5. Single Storm Event

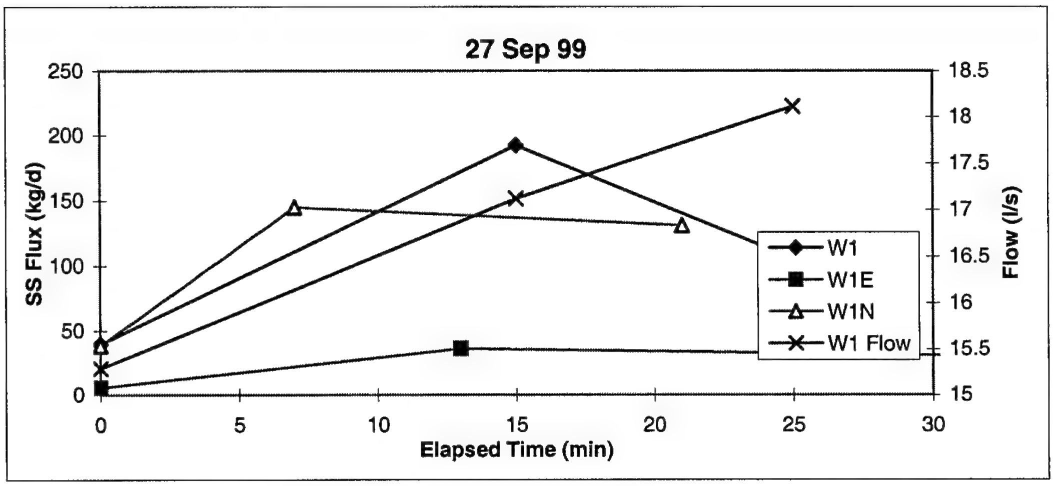



Figure D-6. Single Storm Event

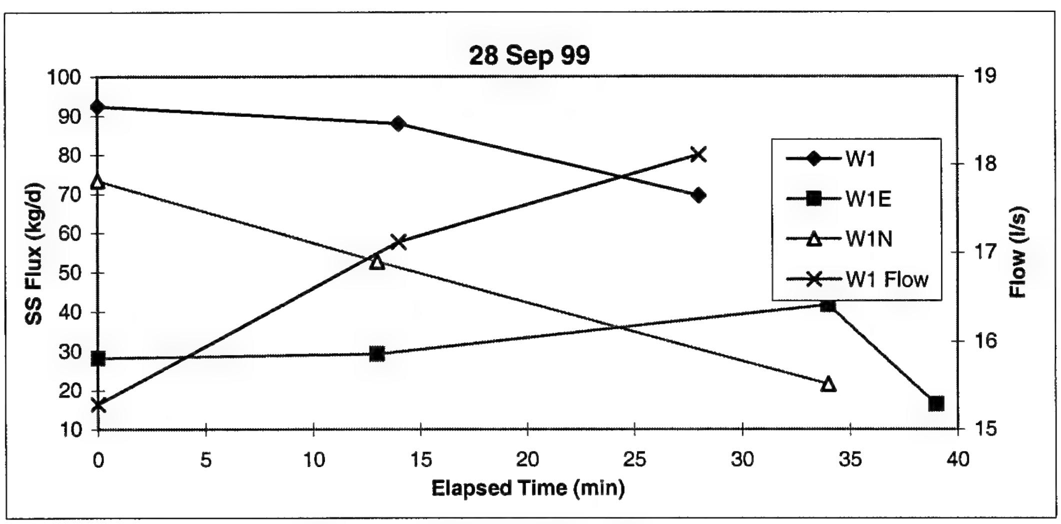



Figure D-7. Single Storm Event

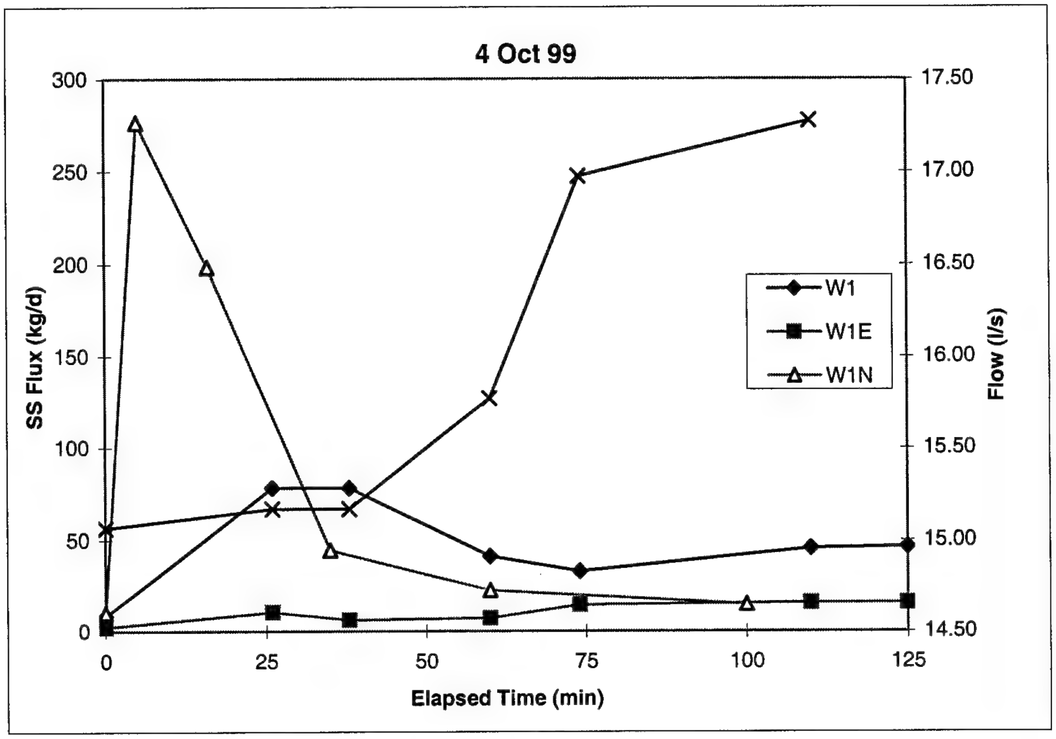



**Figure D-8. Single Storm Event**

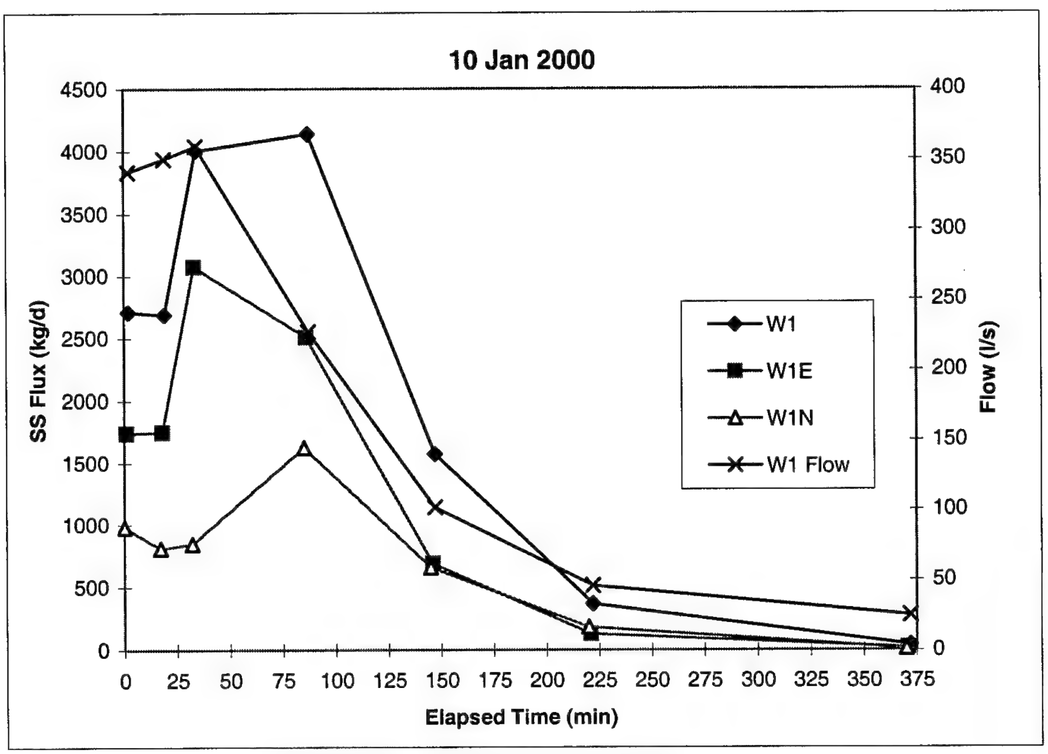
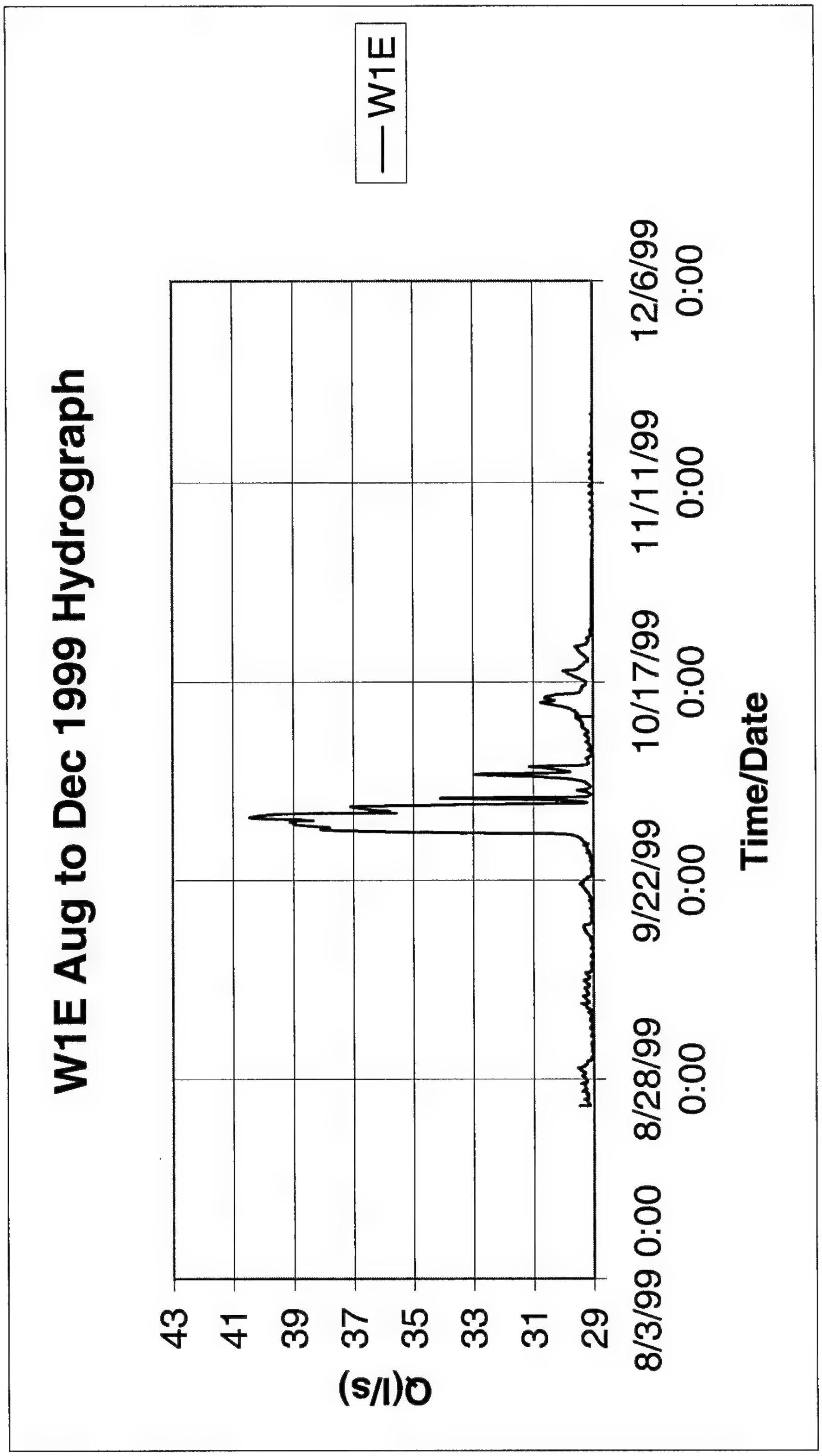



**Figure D-9. Single Storm Event**

# Appendix E

## Continuous Data Logger Discharge Data


W1E Aug to Dec 1999 Hydrograph
Q(l/s)
43
41
39
37
35
33
31
29
8/3/99 0:00
8/28/99 0:00
9/22/99 0:00
10/17/99 0:00
11/11/99 0:00
12/6/99 0:00
Time/Date
W1E

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**PERSONAL COMMUNICATIONS**

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